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THE UNIVERSITY OF ALBERTA

MATCHING AND AMATCHING IN THE BUDGERIGAR

by

© MYRNA J. GUAY

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Matching and Amatching in the Budgerigar" submitted by Myrna J. Guay in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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ABSTRACT

This study investigated differences in acquisition and transfer of matching and amatching in budgerigars. A second purpose was to test for associative symmetry in the transfer of an amatching problem.

No significant differences between matching and amatching were obtained in the acquisition of the first problem. An increase in presolution accuracy for the second matching problem over the level in the first problem, and not for the second amatching problem, was the major difference between the two tasks found in this study. Both groups showed a significant increase of initial color preferences in presolution responding, comparing the second problem to the first.

The principle of associative symmetry was strongly supported by the transfer data for amatching. Only slight negative transfer resulted from a reversal of correct and incorrect comparison values for a second amatching group.

An extended coding hypothesis was proposed, incorporating central associative explanations in the original coding hypothesis. The coding hypothesis accurately predicted the acquisition results and the central associative explanations accounted for the positive transfer results obtained. The extended coding hypothesis accounted for both acquisition and transfer results.

Budgerigars performed matching and amatching tasks at speeds and accuracy levels comparable to those reported elsewhere for chimpanzees, rhesus monkeys and pigeons.

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TABLE OF CONTENTS

	Page
Abstract	iv
Acknowledgements	v
Table of Contents	vi
List of Tables	viii
List of Figures	ix
Introduction	1
Differences in acquisition of matching and amatching	1
Differences in transfer of matching and amatching	6
Associative symmetry in amatching	8
Matching and amatching in budgies	10
Design of the study	11
Method	13
Subjects	13
Apparatus	13
Procedure	14
Results	18
Acquisition of matching and amatching	18
Transfer of matching and amatching	20
Associative symmetry and negative transfer in amatching	23

Page

Discussion 26

Differences in acquisition of matching and amatching 26

Differences in transfer of matching and amatching 27

Associative symmetry and negative transfer in amatching 29

A proposed extension of the coding hypothesis 32

Matching and amatching in budgies 37

Conclusions 39

References 41

Appendix 46

LIST OF TABLES

Table		Page
1	Design of the experiment	15
2	Acquisition of matching and amatching	18
3	Summary of analysis of variance, randomized groups design, for acquisition of stage I	19
4	Transfer of matching and amatching	20
5	Summary of analysis of variance comparing blocks and stages for group M	21
6	Summary of analysis of variance, randomized groups design, for acquisition of stage II	24
7	Summary of analysis of variance comparing blocks and stages for group A_2	25
8	Number of trials for subjects to complete criterion	46
9	Type of presolution preferences displayed by individual subjects	47
10	Average accuracy during overtraining for individual subjects	48
11	Average accuracy per one-quarter blocks of acquisition	48
12	Accuracy in final 20 trials for day 1 in stage II	49
13	Percentage savings scores for individual subjects	49

LIST OF FIGURES

Figure		Page
1	Average accuracy of responding over one-quarter presolution blocks in stages I and II for groups M, A_2 and A_c	22
2	Accuracy of responding during learning stages (I and II) and overtraining (OT) for matching groups M_1 and M_2	50
3	Accuracy of responding during learning stages (I and II) and overtraining (OT) for amatching group A_1	51
4	Accuracy of responding during learning stages (I and II) and overtraining (OT) for amatching group A_2	52
5	Accuracy of responding during learning stages (I and II) and overtraining (OT) for amatching group A_3	53
6	Accuracy of responding during learning stages (I and II) and overtraining (OT) for amatching group A_4	54
7	Accuracy of matching ST and CO^+ stimuli (CO^+ underlined) in stages I and II for matching groups M_1 and M_2	55
8	Accuracy of amatching ST and CO^+ stimuli (CO^+ underlined) in stages I and II for amatching group A_1	56
9	Accuracy of amatching ST and CO^+ stimuli (CO^+ underlined) in stages I and II for amatching group A_2	57
10	Accuracy of amatching ST and CO^+ stimuli (CO^+ underlined) in stages I and II for amatching group A_3	58
11	Accuracy of amatching ST and CO^+ stimuli (CO^+ underlined) in stages I and II for amatching group A_4	59
12	Accuracy of responding to stimulus configurations (CO^+ underlined) in stages I and II for matching groups M_1 and M_2	60
13	Accuracy of responding to stimulus configurations (CO^+ underlined) in stages I and II for amatching group A_1	61

Figure		Page
14	Accuracy of responding to stimulus configurations (CO^{+} underlined) in stages I and II for amatching group A_2	62
15	Accuracy of responding to stimulus configurations (CO^{+} underlined) in stages I and II for amatching group A_3	63
16	Accuracy of responding to stimulus configurations (CO^{+} underlined) in stages I and II for amatching group A_4	64
17	Position preferences in stages I and II for matching groups M_1 and M_2	65
18	Position preferences in stages I and II for amatching group A_1	66
19	Position preferences in stages I and II for amatching group A_2	67
20	Position preferences in stages I and II for amatching group A_3	68
21	Position preferences in stages I and II for amatching group A_4	69
22	Color preferences in stages I and II for matching groups M_1 and M_2	70
23	Color preferences in stages I and II for amatching group A_1	71
24	Color preferences in stages I and II for amatching group A_2	72
25	Color preferences in stages I and II for amatching group A_3	73
26	Color preferences in stages I and II for amatching group A_4	74
27	Correlation of trials to criterion in stages I and II for group A_1	75

INTRODUCTION

The purpose of this study was to investigate possible differences in acquisition and transfer of matching and amatching in budgerigars. A second purpose was to test for the presence of associative symmetry in transfer of amatching.

Differences in acquisition of matching and amatching

Differences between matching and amatching can be described operationally, behaviorally, and conceptually.

At the operational level, matching is a procedure employing a standard stimulus, ST, and two or more comparison stimuli, COs, only one of which is identical to the standard. The experimental subject is required to respond first to the standard and then to choose the identical CO as the correct response. Amatching employs COs that are different from the standard and requires the subject to choose the CO arbitrarily chosen by the experimenter to be paired consistently with a certain ST. Nonmatching or oddity is similar in format to the matching design, except that the subject must choose the CO that is different from the ST as a correct response.

Behavioral differences in matching and amatching acquisition have been reported in several studies but the findings have been contradictory. Ginsburg (1955) compared the behavior of pigeons on matching, amatching and oddity tasks. He found that oddity was considerably easier for his subjects than were the other two tasks. Amatching tended to be of intermediate and matching of greatest level of difficulty, although the differences between amatching and matching were not significant. The easier solution of the oddity problem was similar to the findings of Bitterman

and Wodinsky (1953) for rats, and contrary to the findings of Skinner (1950) that for pigeons matching and oddity behavior did not differ in ease of acquisition. Cumming and Berryman (1965) also present contrary evidence which shows that while amatching was indeed intermediate in difficulty for pigeon subjects, in their study matching was acquired faster and oddity behavior improved at the slowest rate. Their Ss initially responded almost exclusively with position preferences in a matching task. As this control weakened, some color preferences were briefly displayed, then the hue of the ST stimulus gained control. Matching continued to improve to a near perfect level (Cumming and Berryman, 1961). Acquisition of oddity responding for four of six pigeons began at a high level but improved very slowly. Five of the six Ss showed lower position preferences than had those in matching, reduction of which were not correlated with the emergence of the correct behavior (Cumming and Berryman, 1965). Overall accuracy of amatching at various stages in learning for pigeons appeared to be intermediate between those for matching and oddity and the Ss exhibited slightly greater tendencies for position habits than did those in oddity but not up to the level of those in matching (Cumming and Berryman, 1965). The differences for amatching may have been due to oddity type trials in the sequence. However, since neither these trials nor those in which all three stimuli were different were responded to as the subjects did to matching tasks, the experimenters concluded that matching and amatching may be inherently different (Cumming and Berryman, 1965). Meltzer, Maxey and Merkler (1966) reported asymptotic accuracy to be the same for sequential matching and amatching problems for squirrel monkeys. A sequential or adjustable comparisons

technique combines simultaneous ST and one CO presentation; the subject responds to consecutively change COs until a choice response is made to terminate the trial. Because of the findings by Meltzer, Maxey and Merkler (1966) that overstep-trial ratios (the number of times per trial that the subject changes the available CO before making his choice) and right-key responses were higher for amatching and that the differences did not disappear when accuracy levels were equivalent for the two tasks, the authors suggested the possibility that there is a qualitative difference between the problems.

According to Cumming and Berryman (1965) certain hypotheses, such as position preferences, may yield faster learning than others and may help to explain differences in matching and oddity by the kinds of hypotheses each task produces. They used Tolman and Kreshevsky's definition (1933) of hypotheses as the names given to observed relations between stimuli and responses and having these characteristics: systematic, selective and self-initiated. In simultaneous matching almost complete position preferences (exclusive choice of one CO position) were observed (Cumming and Berryman, 1965). Pigeons switched from zero-delay (ST offset at CO onset) to simultaneous (ST on in the presence of the COs) tasks showed an abrupt shift to complete position preferences from partial preferences (Cumming and Berryman, 1965). In form matching, acquisition did indeed proceed more rapidly when a strong position preference was evident (Cumming and Berryman, 1965). Color preferences might hamper acquisition by continual failure to reward the nonpreferred color and by maintaining responding to the preferred color with partial reinforcement of 50 percent.

At a conceptual level, mechanisms that have been proposed to

account for matching behavior yield varying predictions for differences in acquisition of matching and amatching. Central association explanations predict faster acquisition of matching than amatching because of ST-CO^+ similarity. "The 'abstract generalization mechanism' assumes that the abstract relationships of likeness and of difference may function as cues (Nissen, Blum and Blum, 1948, p.73)." This mechanism explained the acquisition of matching behavior as association of approach to likeness and avoidance of difference. Köhler stated that: "...both proximity and similarity of items favor their organization in a unitary experience (1941, p.493)." Whatever favors organization in his view, also favors association and recall. According to Ginsburg (1955) central association mechanisms could account for problem solutions in matching and amatching and with an analysis of the correction method of responding used in his study might also account for obtained differences in the rate of learning. The crucial assumption for matching and amatching in these viewpoints is the importance placed on similarity of stimulus characteristics.

The total stimulus configuration may be controlling responding in a particular direction in matching tasks (Gulliksen and Wolfle, 1938). The configuration explanation states that the difficulty of the problem is inversely related to the distance between the two configurations. Distance is defined as complexity of the discriminations to be made between stimuli. In matching the ST-CO^+ pair of stimuli comprise a configuration in which the color is identical and the size is larger than the size of the CO^-. In amatching three colors must be discriminated and size is not available as a cue, making the configurations more difficult to discriminate than in matching. This explanation would

predict greater difficulty in acquisition of amatching. The results from a study of acquisition and maintenance of matching without a required response to the ST and with simultaneous ST-CO onset suggested that a unitary stimulus explanation was difficult to apply to matching (Eckerman, Lanson and Cumming, 1968). Acquisition and accuracy were both decreased even though a correct CO response was to the larger of the two stimulus configurations as in other matching experiments. The importance of temporal sequencing and/or requiring an ST response were seen by the experimenters as stronger evidence for a mediational explanation of matching than a configuration explanation.

A mediational model of stimulus control of matching behavior was proposed by Cumming, Berryman and Cohen (1965). The mediating event that occurs between the presentation of the ST and a final choice response to a CO is a coding response. The "coding hypothesis" states that the subject "...learns to make an appropriate coding response (r_x) in the presence of a particular standard stimulus (ST_x). In the presence of r_x, the two comparison stimuli (CO_x and CO_y) are presented. The chain $ST_x \rightarrow r_x / CO_x \rightarrow R_x$ is reinforced, while $ST_x \rightarrow r_x / CO_y \rightarrow R_y$ is extinguished (...r_x/CO_x... denotes simultaneous presence...) (Cumming, Berryman and Cohen, 1965, p.437)." Coding responses are acquired to each ST and responses to the COs are reinforced or extinguished to each coding response. The coding hypothesis explains both matching and amatching but makes no predictions of differences in acquisition without an additional assumption that coding responses and comparison stimuli are associated more or less easily if they are similar.

Matching and amatching acquisition have been found to differ in the following: speed of acquisition, overall accuracy, and amount of

presolution position habits in simultaneous problems, and overstep-trial ratios and right-key responses to sequential problems. Different use of hypotheses, such as position preferences, in matching would lead to faster acquisition than for amatching. Central association and stimulus configuration explanations predict faster acquisition for matching because of ST-CO^+ similarity, while the coding hypothesis predicts no difference in speed of acquisition. The first goal of this study was to further explore differences in matching and amatching acquisition, since some findings of differences have been contradictory and explanations of acquisition of these tasks yield different predictions.

Differences in transfer of matching and amatching

Comparisons of these two tasks in transfer to a second problem have not been reported. Data for transfer of simultaneous matching to a second task show that chimpanzees and rhesus monkeys respond with high accuracy on first exposures to matching novel stimuli (Weinstein, 1941; Nissen, Blum and Blum, 1948). The results with pigeons are less clearcut. One study reports high accuracy on the first exposure to a second matching task for one subject and considerable savings in reaching criterion for others (Ginsburg, 1955). Cumming and Berryman (1961) report there was no generalization to the novel stimulus or evidence of the formation of a "matching" concept the first day of generalization testing. The appearance of improvement on the second day of testing was attributed to the requirement of having to learn correct responses to one new ST being easier than the first problem. They also report (1965) that stimulus changes to test for transfer of matching and oddity were initially responded to by a reversion to presolution methods of

responding. Cumming, Berryman and Cohen (1956) used a zero-delay task to study transfer of matching and reported that responding to the new ST was well below chance initially, showing negative rather than positive transfer of matching. Another experiment with the zero-delay technique demonstrated considerable negative transfer to the fourth of the four possible stimulus configurations in a two-choice matching task after acquisition of three of the configurations, indicating that responding in the first task was specific to the stimuli employed and that a general "matching" concept had not been learned (Kamil and Sacks, 1972). No results have been reported for transfer to a second amatching task.

Configuration and central association explanations of matching and amatching behavior would predict greater transfer of matching than amatching: the former because the cue of size of stimuli could have been the basis for solution in the first task and this property would still apply to the second situation and the latter because of the assumption that similarity of stimulus characteristics favors solution. The coding hypothesis would not necessarily predict differences in transfer between the two tasks since in each instance two new coding responses must be acquired to solve the second task. Any differential predictions from the coding hypothesis would be based on assumptions as to which coding responses would be substituted until correct coding responses were acquired to new STs. The problem with making these predictions is the determination of differential coding response strengths before the transfer task. Hypotheses, such as position preferences, might be expected to continue to favor matching in speed of acquisition of the second task.

Matching behavior may or may not show positive transfer de-

pending on the transfer measure and on the species. Data on amatching transfer to a second task is not available. Explanations which differentially favor one task in transfer suggest that matching should show greater transfer because of factors like stimulus similarity, size of stimulus configuration or methods of presolution responding. This study was designed to compare the transfer of matching and amatching to a second problem since this had not been reported and data on matching transfer show variable results.

Associative symmetry in amatching

An additional purpose of this study was to test for the presence of associative symmetry in budgerigars. Asch and Ebenholtz's principle of associative symmetry states that "When an association is formed between two distinct terms, a and b, it is established simultaneously and with equal strength between b and a (1962, p.136)." The principle contains three assertions: first, that a unidirectional or asymmetrical association cannot be established between distinct terms, secondly that associative symmetry is not dependent on the learner's intention or effort, and thirdly that the relation holds for individual associations. Association and direction are two distinct processes. When forward and backward associations are established, they are equal in strength but may vary in availability, defined as a condition of the recall process distinct from the association process. Availability is ease of recall and is related to the subjects' previous opportunities to respond.

The experiments by Asch and Ebenholtz (1962) to test the principle yielded several conclusions. Stationary, simultaneously presented pairs of visual forms with near equal availability were responded to by human subjects without favoring direction. With the standard antici-

pation method of verbal paired associate learning, the pair members were unequally available, backward association was much weaker than forward, and these two were directly related. By equalizing item availability, differences between forward and backward associations were eliminated. This principle has been researched considerably in humans and is generally supported (Ekstrand, 1966). One study with human subjects equated availability of the stimulus pair members by using simultaneous presentation and by pairing numerals and colors which were both deemed highly available stimuli. Symmetry of forward and backward associations was demonstrated by the lack of differences in errors for the directions (Hoats and Gerjuoy, 1966).

Gray (1966) conducted a test of the Asch-Ebenholtz principle using a zero-delay situation. By requiring responses first to the ST then to the CO^{+} stimulus, he concluded that "availability" was equalized and that this would account for his finding that forward associations were not significantly stronger than backward associations. Three pigeons were trained to a criterion of 75% correct for two consecutive sessions of 56 trials and then given three tests of 28 unreinforced trials for backward, forward and then backward associations. Two subjects showed significant backward associations.

The present study aimed to extend the findings on associative symmetry in humans and pigeons to the budgerigars. In the present study the simultaneous technique should more nearly equate availability than in Gray's zero-delay task (Asch and Ebenholtz, 1962). A higher accuracy is usually found in simultaneous than zero-delay matching tasks (Cumming and Berryman, 1965) and this should facilitate testing for the presence of symmetry by reducing error influences. A savings technique

of testing for symmetry avoids any influences that extinction processes may have on accuracy during the test period. The present study also employs a larger group of subjects, a different species, a linear rather than triangular stimulus array, and different combinations of ST-CO^+ pairs. In this study if animals continue criterion level responding when the stimulus positions are reversed, so that former STs become COs, this would support the principle of associative symmetry.

Matching and amatching in budgies

The final goal of the present study was to extend the application of the designs of matching and amatching to a new species, the budgerigar (Melopsittacus undulatus). Brockway has published several studies on the biology and natural behaviors of budgerigars (1962, 1964a, 1964b, 1965 and 1967). Recently, psychological studies have been conducted with budgerigars conditioning vocal responses (Ginsburg, 1960), demonstrating the occurrence of observational learning (Dawson and Foss, 1965), studying the preference for mirror-image stimulation (Gallup and Capper, 1970), measuring flicker thresholds (Ginsburg and Nilsson, 1971) and studying discrimination and maze behavior (Cogan, Inmam and Gambrel, 1971).

Species differences in matching and amatching are apparent in comparing several investigations of these tasks. Children showed greater transfer of matching on generalization tests than did rhesus monkeys (Weinstein, 1941). Chimpanzees learned matching faster than rhesus monkeys (Nissen, Blum and Blum, 1948). Intra-dimensional transfer occurred more readily in rhesus monkeys (Jackson and Pegram, 1970) than in pigeons (Ginsburg, 1955, Cumming, Berryman and Cohen, 1965; Cohen, 1969). Generalized matching was demonstrated with chimpanzees (Nissen,

Blum and Blum, 1948) and with rhesus monkeys (Mishkin, Prockop and Rosvold, 1962). Pigeons successfully acquired matching behavior with an adjustable comparisons method of stimulus presentation (Cohen, 1969) but sequential matching and amatching problems were only acquired by squirrel monkeys when fading techniques of presentation of stimuli were used (Meltzer, Maxey and Merkler, 1966). The importance of the CO^{-} may be different for some primates and for pigeons (Harlow, 1951; Ferster and Hammer, 1966; Malott, Malott and Svinicki, 1967).

Budgerigars were chosen for the present study to compare with matching and amatching data in pigeons. The brain of the budgerigar is more evolved than that of the pigeon with larger cerebral indices for the areas of the cerebellum and the hemispheres. The cerebral index utilizes a basic unit, the "...mass of the brain stem rest of a gallinaceous bird of a given body weight," and then relative mass development for brain parts is obtained in relation to this unit (Marshall, 1961, p.34). The purpose of utilizing different species is to extend the generality of findings in acquisition and transfer of matching and amatching tasks, since some species differences have previously been noted.

Design of the study

The present study employed two stages of learning matching and amatching tasks. The first stage was designed to compare possible acquisition differences in the two tasks. In the second stage, new stimuli were given to the matching Ss and to the amatching control Ss to study the effects of learning a second problem for which associations learned previously had no bearing on the solution. A second amatching

group experienced a reversal of stimulus roles in which STs were now COs and vice versa. For this group, if the associations learned in stage one were equidirectional then Ss would show high positive transfer in the second stage and this would support the principle of associative symmetry. A third amatching group experienced stimulus role reversal in the second stage and also a reversal of correct and incorrect COs for each ST. For this group, the associations learned in the first stage might be expected to interfere with second stage performance.

The configuration and central association explanations suggest that matching should be acquired faster and should show greater transfer than amatching. The coding hypothesis would predict no differences in acquisition and transfer of matching and amatching. A central association explanation would predict a finding of associative symmetry and negative transfer of amatching since the associations learned in the first stage would control responding in the second stage.

METHOD

Subjects

Twenty-eight male budgerigars, Melopsittacus undulatus, served as subjects. The Ss were approximately two to three months of age when obtained from local pet stores. They were maintained in individual cages with free access to gravel, water and cuttlebone. After free-feeding weight was established on Hartz Mountain budgie seeds, gradual food deprivation was introduced, reducing access to food by several hours each day until food was available for approximately 15 minutes daily. This resulted in body weight maintenance at about 80% of free-feeding weight. A twenty-ninth subject failed to display any progress in amatching and was discontinued after one thousand trials.

Apparatus

The stimulus panel contained three one-half inch diameter, circular Plexiglas windows one and one-half inches apart from center to center and arranged horizontally above an automatic feeding cup. During testing the subject's home cage was placed in front of the apparatus. Opening the cage door allowed access to the stimulus panel and feeder. When a response key was operative, it was illuminated from the rear with light passed through a colored plastic filter. Prior to each trial, switches on the control panel were set to determine the colored stimulus for each key. At the beginning of a trial only the center key was illuminated with an ST stimulus. A response to the center key turned on the two side keys with two CO stimuli and the center key remained illuminated. The response to the center key rendered its pen

inoperative until the next trial. A response to a side key whether correct or incorrect, terminated the trial, darkened the keys, and advanced the apparatus to the next trial in the sequence. Correct responses were reinforced by three seconds access to the feeder cup containing Hartz Mountain budgie seeds. Each trial was followed by a mean variable intertrial interval of 15 seconds.

Procedure

Pretraining began with the familiarization to the appearance of the apparatus and learning to feed from the feeder cup. Once feeding behavior occurred readily, presentation and removal of the feeder with the motor was introduced. By a successive approximations technique, key pecking was acquired to the center stimulus key, illuminated by white light. The final step in pretraining was the establishment of a response chain of a peck to the center white key followed by a response to one of the colored side keys, with the other side key remaining darkened. Two consecutive sessions (80 trials) of correct responding to the chain were required before the matching or amatching problems were first presented.

The design of the experiment involved two stages of learning and six groups of subjects. Two groups, M_1 and M_2, received training on simultaneous matching to sample with two colored stimuli in stage I and then learned to match two different colors in stage II. Amatching tasks were provided for the four remaining groups, A_1 - A_4, using four colored stimuli in stage I. In stage II, A_1 experienced the same four stimuli with the same correct combinations but reversing the roles of STs and COs. A_2 had reversed roles of STs and COs as well as reversed

correct and incorrect values for each possible combination. Groups A_3 and A_4 were given two new stimuli in place of the former STs and the former STs became the new COs. The same task was presented to all amatching groups in Stage II. The stimuli for each group at each stage are presented in Table 1.

Table 1. Design of the experiment.

Groups	N	Stages I	Stages II
M_1	3	R-R G G-G R	B-B Y Y-Y B
M_2	3	B-B Y Y-Y B	R-R G G-G R
A_1	6	B-R Y Y-G B	R-B G G-Y R
A_2	6	B-G Y Y-R B	R-B G G-Y R
A_3	5	V-R O O-G V	R-B G G-Y R
A_4	5	O-R V V-G O	R-B G G-Y R

M - matching, A - amatching, R - red, G - green, B - blue, Y - yellow, V - violet, O - orange. STs are represented in the center of the cells. Correct COs appear to the left and incorrect COs appear to the right.

The matching groups, M_1 and M_2, received reversed orders of stimuli for stages I and II in order to control for possible acquisition differences for different colors. Only three Ss were used in each group since no differences were predicted from order of stimuli and the groups would later be combined into one matching group, M. For amatching groups, A_3 and A_4, no differences in acquisition were

predicted for the different correct stimulus pairs in stage I. They would be combined into a single group, A_c, to compare with M to look for general differences in matching and amatching in learning a second task in which associations learned in the first task would not yield solutions. A_c, would also serve as a control group to separate the effects of learning a second amatching task from the predicted effects of associative symmetry for A_1 and negative transfer for A_2.

Color stimuli were chosen since Plath (1935) demonstrated the presence of good spectral discrimination in the budgerigar and since Cumming and Berryman (1965) stated that for pigeons matching of hues is more rapidly acquired than is the matching of forms.

Daily training sessions consisted of approximately forty trials. Only the last 20 trials per day were used to calculate accuracy levels, utilizing all previous trials as warmups. The criterion of acquisition for stage I was 16 or more correct out of the final 20 trials on two consecutive days. This (80%) level differs from chance, 50% accuracy on a two-choice problem, at the .05 level. Following attainment of this criterion, all subjects continued on stage I problems for seven days of overtraining before being shifted to stage II. Ellis (1965) summarizes results from human verbal learning and animal discrimination learning which show that, in general, increased practice on original learning tasks facilitates positive transfer. Seven days of overtraining would allow subjects to respond at high accuracy levels for a large number of trials when compared to the acquisition of stage I. The stage II criterion was two consecutive sessions with 16 or more correct choices out of the final 20 trials.

Four different sequences of 20 trials each were made up from selected random orders, using Gellerman sequences (Hilgard, 1964), to insure that correct positions and colors were equally represented and that colors occurred equally in both positions. No more than three consecutive trials, correct positions, or correct colors were identical. One sequence was presented twice during one daily session for two sessions, then another was introduced for two sessions until all four sequences had been completed. The order was repeated throughout training and overtraining sessions.

RESULTS

All data presented in the results are combined into group performance. Individual data are available in the appendix.

Acquisition of matching and amatching

The acquisition data presented in Table 2 include mean trials to criterion, mean number of correct responses on day 1 and mean number of correct responses during overtraining. All responses during acquisition were used to calculate the first measure. The latter two are based on the final 20 trials of the sessions designated.

Table 2. Acquisition of matching and amatching

	M_1	M_2	A_1	A_2	A_3	A_4
Mean trials criterion	723.3	666.3	661.5	883.3	934.4	946.0
Mean correct on day 1	8.0	9.0	9.5	8.83	9.6	10.0
Mean correct in overtraining	17.33	17.14	18.10	18.22	16.63	16.60

There were no significant differences in acquisition between matching and amatching. A randomized groups analysis of variance on mean trials to criterion showed no differences between groups on this measure, $F(5,22) = .687$, $p>.05$, (Table 3). Matching groups M_1 and M_2 did not differ significantly on mean trials to criterion, $t(4) = .17$, $p>.05$. The results of these groups were pooled for later comparisons and designated as group M. Groups A_3 and A_4 did not differ in acqui-

RESULTS

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Acquisition of matching and amatching

The acquisition data presented in Table 2 include mean trials to criterion, mean number of correct responses on day 1 and mean number of correct responses during overtraining. All responses during acquisition were used to calculate the first measure. The latter two are based on the final 20 trials of the sessions designated.

Table 2. Acquisition of matching and amatching

	M_1	M_2	A_1	A_2	A_3	A_4
Mean trials criterion	723.3	666.3	661.5	883.3	934.4	946.0
Mean correct on day 1	8.0	9.0	9.5	8.83	9.6	10.0
Mean correct in overtraining	17.33	17.14	18.10	18.22	16.63	16.60

There were no significant differences in acquisition between matching and amatching. A randomized groups analysis of variance on mean trials to criterion showed no differences between groups on this measure, $F(5,22) = .687$, $p>.05$, (Table 3). Matching groups M_1 and M_2 did not differ significantly on mean trials to criterion, $t(4) = .17$, $p>.05$. The results of these groups were pooled for later comparisons and designated as group M. Groups A_3 and A_4 did not differ in acqui-

sition as measured by mean trials to criterion, $t(8) = .05$, $p>.05$, and were pooled into group A_c for transfer comparisons. The acquisition results for all four amatching groups were combined to compare with group M. The t tests on the measures in Table 2 showed no significant differences between matching and amatching for mean trials to criterion, $t(26) = .86$, $p>.05$, mean correct responses on day 1, $t(26) = 1.44$, $p>.05$, or mean correct responses during overtraining sessions, $t(26) = .46$, $p>.05$.

Table 3. Summary of analysis of variance, randomized groups design, for acquisition of stage I.

Source of Variation	Sum of Squares	d.f.	Mean Square	F
Treatments	417,976.34	5	83,595.27	.687
Error	2,675,435.37	22	121,610.70	
Total	3,093,411.71	27		

Matching and amatching Ss did not significantly differ in type of initial response preferences displayed during acquisition, $\chi^2(1) = 1.98$, $p>.05$. Preferences were consistent selections of one color or one position, occurring 75 - 100% of the final 20 trials of sessions. Preference types noted in the data were color and position. Initial preferences were those displayed first during the presolution period. The predominant type during acquisition of both tasks was a position preference: for five of six matching Ss, and for 14 of the 22 amatching Ss initially and for 18 of the 22 just prior to criterion level responding. No consistent differences were apparent in percentage level of preference responding for matching and amatching. Twenty-six Ss

first solved a stimulus configuration containing either a preferred color or position, $z = 4.34$, $p<.01$. Stimulus configuration solution was defined as a maintained accuracy of 80-100% correct responding.

An examination of the curves of acquisition for the whole tasks, for separate STs and for separate configurations revealed no consistent differences between matching and amatching in the form of the curves.

There were no significant differences in acquisition of matching and amatching obtained from analyses of mean trials to criterion, mean correct responses on day 1, and mean correct responses in overtraining, or from examinations of acquisition curves and preference data.

Transfer of matching and amatching

Table 4 presents the mean trials to criterion and mean number of correct responses on day 1 in learning the second matching or amatching problems. The first measure includes all trials to criterion; the second is based on the final 20 trials of the session.

Table 4. Transfer of matching and amatching.

	M	A_1	A_2	A_c
Mean trials to criterion	515.0	112.7	615.8	465.0
Mean correct on day 1	10.17	16.5	9.67	9.1

The t tests for differences between groups M and A_c showed no significant differences in mean number of trials to criterion, $t(14) = .42$, $p>.05$, in mean number of correct responses on day 1, $t(14) = 1.07$, $p>.05$, or in percentage savings scores, Mann-Whitney $U = 13$, $p>.05$. The percentage savings for Ss were computed on the number of trials to criterion for the first and second problems, by the formula $\frac{I - II}{I}$.

Table 5. Summary of analysis of variance comparing blocks and stages for group M.

Source of Variation	Sum of Squares	d. f.	Mean Square	F
A: Stages	72.33	1	72.33	19.08*
Error (a)	37.94	10	3.79	
B: Blocks	43.22	3	14.41	5.07*
A x B: Stages x Blocks	7.75	3	2.58	.91
Error (b)	85.13	30	2.84	
Total	246.37	47		*p<.01

Accuracy during the presolution period of stage II was significantly higher than in stage I for matching group (Figure 1). The mean number of correct responses on the final 20 trials of one-quarter blocks of presolution days were calculated to obtain a comparison of the group acquisition of the two problems. A blocks x stages analysis of variance revealed that there was a significant difference between the stages, $F(1,10) = 19.08$, $p<.01$, (Table 5), a significant increase over blocks, $F(3,30) = 5.07$, $p<.01$, (Table 5) and that the form of the curves for the two stages was essentially similar, $F(3,30) = .91$, $p>.05$, (Table 5). Group A_c showed essentially similar presolution acquisition curves for the two stages (Figure 1). The matching and amatching groups, M and A_c, differed significantly on mean number of correct responses on the final 20 trials of blocks 1, 2 and 3 of stage II, $t(14) = 1.87$, $p<.05$; $t(14) = 2.33$, $p<.05$; and $t(14) = 4.32$, $p<.01$, respectively.

There were no significant differences in initial preference type

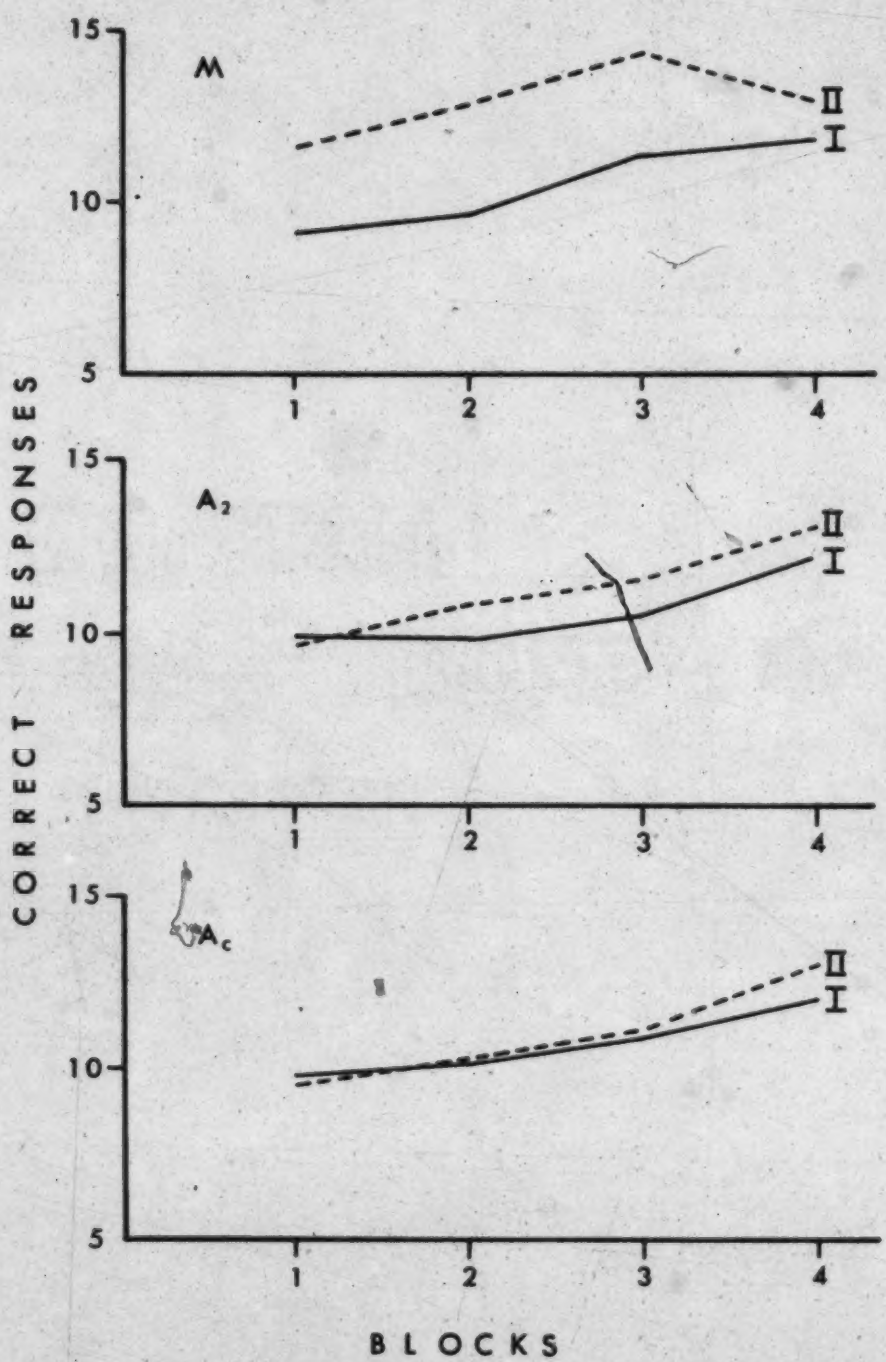


Figure 1. Average accuracy of responding over one-quarter presolution blocks in stages I and II for groups M, A_2 and A_c.

displayed in acquisition of a second problem for matching and amatching, M and A_c, $\chi^2(1) = .48$, $p>.05$. These two groups displayed more initial color than position preferences in the second presolution period. The change in initial preference type from position in the first problem to color in the second problem was significant for both groups M: $\chi^2(1) = 5.49$, $p<.02$; A_c: $\chi^2(1) = 7.27$, $p<.01$.

The increase in presolution accuracy for the second matching problem and not for the second amatching problem was the major difference between the two tasks found in this study. No significant differences in transfer to a second problem for matching and amatching were found in mean number of trials to criterion, mean number of correct responses on day 1 of the second problem, in percentage savings scores or in types of initial preferences displayed in the presolution period. Both groups showed a significant change of type of preferences initially displayed in the first and second tasks, from position in the first to color in the second.

Associative symmetry and negative transfer in amatching

A randomized groups analysis of variance on the mean trials to criterion for stage II showed significant differences between groups on this measure, $F(3,24) = 5.52$, $p<.01$, (Table 6). Multiple comparisons among the group means (Dunn, 1961) showed this significance was due to the mean score of the associative symmetry group, A_1. The difference between A_1 and A_c on mean trials to criterion (Table 4) was significant at the .05 level, $t(22) = -2.96$. Significant results were also obtained for the mean number of correct responses on day 1 (Table 4), $t(14) = 5.32$, $p<.01$, and for percentage savings scores, Mann-Whitney $U = 2$, $p<.001$. The number of trials required for the A_1

subjects to complete criterion for the two stages were significantly correlated, $r = .75$, $t(4) = 2.77$, $p<.05$, indicating a possible relationship between ease of acquisition of the first task and the strength of the backward associations, measured in stage II.

Table 6. Summary of analysis of variance, randomized groups design, for acquisition of stage II.

Source of Variation	Sum of Squares	d.f.	Mean Square	F
Treatments	866,826.8	3	288,942.27	5.52*
Error	1,256,494.16	24	52,353.92	
Total	2,123,320.96	27		*p<.01

Group A_2 for which negative transfer was predicted did not significantly differ from A_c on mean trials to criterion, $t(14) = 1.27$, $p>.05$, (Table 4), on mean number of correct responses on day 1 of stage II, $t(14) = .40$, $p>.05$, (Table 4), or in percentage savings scores, Mann-Whitney $U = 25$, $p>.05$. Although some improvement in presolution accuracy for A_2 in stage II appears to have occurred (Figure 1), the stages did not significantly differ in level, $F(1,10) = 1.05$, $p>.05$, (Table 7). The only significant effect in the blocks x stages analysis of variance was the increase in accuracy over blocks, $F(3,30) = 13.86$, $p<.01$, (Table 7). Two A_2 subjects, A_2-1 and A_2-2, showed negative transfer as revealed by percentage savings scores of -75 and 0 respectively. Percentage transfer for these two was -36.95 (Murdock's formula 1957). The remaining A_2 group members showed positive transfer to the second problem, (5.23, Murdock, 1957).

Table 7. Summary of analysis of variance comparing blocks and stages for group A_2.

Source of Variation	Sum of Squares	d.f.	Mean Square	F
A: Stages	6.66	1	6.66	1.05
Error (a)	63.6	10	6.36	
B: Blocks	51.96	3	17.32	13.86*
A x B: Stages x Blocks	3.08	3	1.03	.82
Error (b)	37.5	30	1.25	
Total	162.8	47		

*p<.01

Significant evidence for associative symmetry in amatching was found in mean trials to criterion of the second problem, in percentage savings scores, and the mean number of correct responses on day 1 in stage II. Only two A_2 subjects showed the predicted negative transfer. The A_2 group results did not significantly differ from A_c on mean trials to criterion, mean number of correct responses on day 1 in stage II or percentage savings scores.

DISCUSSION

Differences in acquisition of matching and amatching

The present study showed no significant differences in acquisition between matching and amatching on any of the variables measured.

This result was predicted by the coding hypothesis since each task is solved by learning to make two correct coding responses and then acquiring the correct overt response to each. The configuration and central association explanations both predicted matching to be easier to acquire: the former because the identical stimulus would allow the cue of stimulus size to be used in solution and the latter because stimulus similarity and identity are assumed to facilitate the formation of associations.

The assumption of a response to identity is crucial to central association views of learning (Kohler, 1941). Pigeons and rhesus monkeys have demonstrated an ability to learn to respond to similarity and identity (Weinstein, 1945; Ginsburg, 1955; Wright, French and Riley, 1968) but they do not initially show this type of responding and one study with pigeons demonstrated that previously strong responses to COs or coding responses to STs rather than stimulus similiarity controlled the responding to new STs (Cohen, 1969). The absence of significantly greater acquisition of matching over amatching in stage I of this study casts further doubt on the validity of this assumption.

Amatching tended to be more difficult to acquire as measured by mean trials to criterion. This result is more similar to the findings for pigeons reported by Cumming and Berryman (1965) than to the findings by

Ginsburg (1955). Cumming and Berryman (1965) speculated that the presence of oddity trials in the sequences of the amatching problem in their study might account for some of the differences found but that inherent differences may exist between the two problems of matching and amatching. The oddity trials were those in which either a response to the odd stimulus or a response to the ST-CO^{+} pairs would be correct. The present study employed stimuli and sequences similar to those in Ginsburg's study but changed to a noncorrection from a correction method of trial advancement. Ginsburg (1955) suggested that a correction requirement might have reinforced oddity responding in a chain to respond first to the odd and then to the matching stimulus in his study.

The present study excluded the effects of reinforcement of oddity responding by presenting three different stimuli on each trial in amatching and by employing a noncorrection requirement. Only a slight difference between matching and amatching in mean trials to criterion, in favor of matching, was found.

The coding hypothesis made no prediction of significant differences in acquisition of matching and amatching. Since differences usually reported between these two tasks (such as speed of acquisition, overall accuracy, presolution preferences and form of learning curves) did not appear, the present findings do not support a speculation of inherent differences in acquisition of matching and amatching.

Differences in transfer of matching and amatching

Matching Ss showed a significant increase in presolution accuracy in the second problem as compared to the level for the first problem, and amatching Ss did not. No other variables demonstrated significant

differences in transfer between the two problems. Both groups displayed more initial color preferences in the second problem than in the first.

The coding hypothesis made no prediction of differences in transfer of the two tasks since both groups were required to learn coding responses to two new stimuli and to learn the correct overt responses to each. This approach failed to predict the presolution accuracy increase for matching. The learning of coding responses in the first task might have influenced the Ss tendency to respond to color as reflected in the increase in initial color preferences in the transfer problem.

The configuration explanation predicted greater transfer of matching than amatching because stimulus size would still obtain as a cue to solution in the second problem. If acquisition of stage I occurred as a result of responding in the direction of the larger stimulus area, then matching Ss should have shown immediate transfer to a second problem. In amatching, four new total configurations would have to be discriminated and directional responding to them acquired. Little transfer to a second amatching problem would be expected. The increase in presolution accuracy for matching Ss but not amatching suggests that a configurational cue may have been employed. However, the increase in color preferences for matching as well as amatching Ss indicated that the cue being responded to was probably color rather than size. Since only slight positive transfer for matching was found and since stimulus size was not demonstrated to be in control, the configurational prediction of transfer differences between the two groups is not well supported.

The central associative explanation also favored matching in a transfer task because stimulus similarity or identity favors faster

associative formation. Matching Ss did show greater transfer on one variable, the increase in presolution accuracy, however amatching Ss tended to show more transfer than matching in some other measures, such as savings in mean trials to criterion. The change to color preferences could be the result of learning associations in the first problem on the basis of color, according to the central associative view.

This portion of the study shows some evidence that the Ss were learning to respond to stimulus similarity or identity in terms of color and the results were more predictable from a central associative approach than from a configuration explanation or a coding hypothesis.

Associative symmetry and negative transfer in amatching

Strong evidence for positive transfer was found for group A_1 in mean trials to criterion, in mean number of correct responses on day 1 and for percentage savings scores in the second problem.

The rapid reversal of roles between STs and COs that was demonstrated by subjects in group A_1 in stage II, demonstrated the phenomenon of backward association and supports the view of Asch and Ebenholtz (1962) that associations that are formed between two stimuli in a paired-associate learning situation are symmetrical, that is, either stimulus can serve as a stimulus for the other. When subjects learned to choose blue when presented with a red standard and to choose yellow when presented with a green standard, they appeared to learn that blue and red were a stimulus combination, as were yellow and green. The findings of the present study are congruent with data on humans which support the associative symmetry principle when item availability is equalized.

Although the association between ST-CO^+ pairs in stage I could not be explained in terms of central association viewpoints regarding the importance of stimulus similarity, these explanations predict that once the STs and COs were associated, the occurrence of either in stage II should initiate a response to the other. The strong backward associations found in stage II for group A_1 suggest that ST-CO^+s had come to be reacted to as associated stimuli. The strength of the association was predictable from the number of reinforcements in stage I after chance responding ceased. The strength of backward associations was also directly related to the number of trials required to learn the association initially. Fewer numbers of trials to criterion meant that high accuracy responding (during overtraining) would have a greater strengthening effect on the association since reinforcement density over the entire stage was greater. The high correlation between stage I and stage II acquisition suggests a difference in subjects in ease of establishing associations.

An explanation of stage I acquisition by A_1 subjects as learning to respond in a particular direction according to the total stimulus configuration would not predict this immediate high level of accuracy in stage II. All of the configurations in stage II were different from those in stage I. A carry-over of a general effect of learning directional responding would have yielded chance accuracy until the new configurations and directions for each were learned.

The coding hypothesis (Cumming, Berryman and Cohen, 1965) states that coding responses are learned to the STs and not to the COs. Initial responding to the second A_1 problem would occur, according to the coding hypothesis, by coding response substitution. In stage II

if subjects responded to the new STs with the old coding responses, the new COs would be responded to according to the coding response substituted (Cohen , 1969). For example, on a new RYG configuration, if yellow were coded as red and red had been paired with blue, then the absence of a blue CO to which to respond would mean that chance responding would occur until the coding response to yellow was learned and its correct CO was associated with it. Since responding to COs on the basis of similarity to old COs usually does not occur (Cohen, 1969), then the ST-CO^+ association learned in stage I would not necessarily be predicted to control stage II responding. If coding response substitution did not take place, then chance responding would occur until the new coding responses and their response attachments were learned. Either with or without coding response substitution, the coding hypothesis is unable to predict the obtained associative symmetry.

The central associative explanation predicted the obtained associative symmetry. Configuration and coding hypothesis approaches predicted initial chance performance and gradual acquisition rather than high positive transfer.

The group for which negative transfer was predicted did not significantly differ from the amatching control group in mean trials to criterion, mean number of correct responses on day 1 or percentage savings scores for the second problem. The predicted negative transfer for A_2 was found for only two of the six subjects in the group.

Negative transfer would not be predicted using a coding hypothesis. If coding response substitution were to take place, then chance responding should occur because the correct CO for response attachment was

no longer present as a CO. Either coding response substitution or chance responding without coding substitution would occur until the new coding responses and response attachments were acquired.

A configurational approach would also predict chance responding until the new directions to the new configurations were acquired. Slight transfer effects might occur if the configurations were difficult to discriminate from those learned in the first stage but the effects could be either positive or negative and for A_2 should appear immediately. As a group, transfer effects on day 1 were not apparent.

A central associative explanation would predict strong negative effects from reversing the CO correct and incorrect values since the associations learned in the first problem would be expected to interfere with second problem performance. This explanation accurately predicted negative transfer for only a portion of the group. The remainder of the Ss showed positive, rather than negative, transfer.

The configurational and coding hypothesis explanations predicted the A_2 group results for transfer to a second problem. The results were contrary to the central associative prediction of a strong negative transfer. None of the explanations accounted well for the division of the group results into positive and negative transfer.

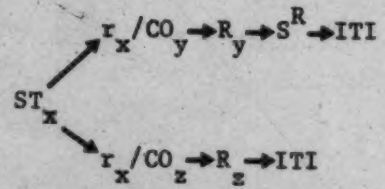
A proposed extension of the coding hypothesis

The coding hypothesis (Cumming and Berryman, 1965) better accounts for the acquisition findings of this study than the other explanations that were considered. An extension of its concepts seems warranted by the difficulties encountered in explaining transfer in matching and amatching. The authors of the coding hypothesis predict that

stimulus generalization can occur to either STs and COs (Cumming and Berryman, 1965). This suggests that coding responses to COs, as well as to STs, probably occur in learning matching and amatching problems. The central associative explanation better accounted for positive transfer in the present study. Conceptually, the proposed extension becomes a blending of the original coding hypothesis with central associative explanations.

The extension incorporates two more types of coding responses, one to COs and one to the ST-CO association. Learning of coding responses would begin to develop at different times in acquisition: coding responses to the STs would begin to develop first, then CO coding responses would appear, finally the coding response to the association would begin development. The coding responses are strengthened by reinforcement. The strongest coding response controls the responding for each trial.

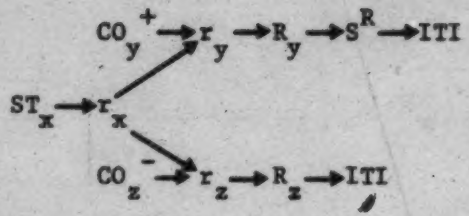
Initially the events for each trial would be diagrammed as did Cumming and Berryman (1965):



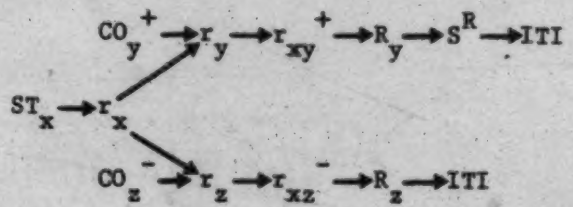
The symbols mean: ST_x, standard stimulus of x value; r_x, coding response to x value; CO_y and CO_z, comparison stimuli of y and z values; R_y and R_z, responses to y and z stimuli; S^R, reinforcing stimulus; and ITI, intertrial interval. In all diagrams the coding responses and comparison stimuli are present simultaneously. In matching, the x and y values are identical.

As coding responses to the COs develop then the events of a trial

would occur in this sequence:


$CO_y^+ \rightarrow r_y \rightarrow R_y \rightarrow S^R \rightarrow ITI$
$ST_x \rightarrow r_x$
$CO_z^- \rightarrow r_z \rightarrow R_z \rightarrow ITI$

As reinforcement strengthens the association between r_x and r_y and between r_x and r_z then the coding response to the association develops:


$CO_y^+ \rightarrow r_y \rightarrow r_{xy}^+ \rightarrow R_y \rightarrow S^R \rightarrow ITI$
$ST_x \rightarrow r_x$
$CO_z^- \rightarrow r_z \rightarrow r_{xz}^- \rightarrow R_z \rightarrow ITI$

The r_{xy} and r_{xz} coding responses would contain information about elements of both the stimuli plus the nature of the association or relation between the stimuli, such as positive or negative, or similar or different. The negative association develops last and provides the subject with information about negative stimulus associations. This allows exclusive, as well as inclusive, responding to stimuli.

The extended coding hypothesis would predict a slight advantage in initial acquisition for matching over amatching since the coding responses learned to COs would be more similar to those learned to the STs than for the amatching group. Coding responses being learned to STs are gradually used for COs. The subjects still have the same number of coding responses to STs and to associations to learn in both groups. The present study found acquisition of matching occurred sooner but the finding was not significant. Coding responses, such as a response to oddity, could be in initial control for matching. This would attenuate differences in initial acquisition of the two problems since

the old coding responses would have to be reduced in strength before new ones could emerge.

Initial control of responding by variables such as position, color or oddity preferences would be the result of strong coding responses for these stimulus values. As learning progresses the aspects of the stimuli relevant to problem solution become the qualities that are preserved in the coding. Greater reinforcement of one dimension value over another would result in differences in coding response strength and should be reflected in greater accuracy or earlier acquisition of preferred stimulus values. The present study demonstrated that preferred values were usually learned first.

The extended coding hypothesis would predict generalized matching behavior after sufficient numbers of coding responses to associations between identical stimuli had been learned, since the coding responses for identity would then control responding. The strength of responding to nature of an association would be acquired more slowly than coding responses to STs and COs so considerable strengthening would have to occur before a substitution of a coding response to similar stimuli would take place in a new situation. The increase in presolution accuracy in a second matching problem lends some support to this prediction.

The coding responses to associations for amatching already contained learned elements to stimuli from stage I acquisition. The significantly low accuracy of responding for two amatching control subjects at the beginning of stage II supports the suggestion that ST coding responses learned in stage I were used in stage II when the same stimuli were then COs. The new STs were responded to by substitution of the

other coding responses learned in stage I: blue was responded to as violet and yellow as orange. This substitution along with transfer of the coding responses to associations in stage I yielded low accuracy responding, since a coding response to orange was now paired with one for green rather than with red as in stage I.

The associative symmetry found in this study is readily predicted by the extended model because all coding responses (to STs, COs and to associations) are still relevant to problem solution in stage II. For those subjects not showing high accuracy on day 1 the strength of a coding response to red and the strength of the BR pair were greater than for other stimuli, suggesting that the coding response to a YG association did not yet control responding for that pair. The correlation found between number of trials to criterion for the two stages suggested differences in subjects in ease of developing and in strength of coding responses. In A_1 stronger associations were obtained with subjects taking fewer trials to criterion. The effect of overtraining would be to strengthen the associations and would do more so for those subjects who had experienced fewer trials during which the associations were weak or absent. The proportion of high accuracy responding to total responding was greater for faster subjects so the coding responses to associations should have been proportionately stronger than for slower subjects.

The positive savings found for most subjects in A_2 where negative interference had been predicted would be explained by the extended coding hypothesis as a result of having only to learn a different nature of the association while the coding response to the association continued to contain the elements of the x and y learned from the ST and CO

coding responses. The coding responses to STs and COs would continue to be relevant. If the stage I coding responses to associations were relatively weak then the change in nature should be learned more rapidly than if they were strong. Most of the subjects showing positive savings had shown relatively long presolution periods in stage I so the strengthening of coding responses to associations during the overtraining period would be assumed to be less than for faster subjects.

The extended coding hypothesis has the same difficulty as the original proposed by Cumming and Berryman (1965) in predicting what coding responses will be used as substitutes in a new situation until new, appropriate ones are learned. They predict that the strongest will control responding but an independent measure of coding response strength is not always available in advance. Stimulus similarity is often not a reliable indicator (Cohen, 1969). However, the addition to the coding hypothesis of coding responses to COs and associations was beneficial in accounting for associative symmetry and negative transfer in amatching and in accounting for differences in matching and amatching transfer in this study.

Matching and amatching in budgies

Budgies acquired matching behavior at speeds and accuracy levels comparable to those previously reported for chimpanzees, rhesus monkeys and pigeons. Chimpanzees required about 2,000 trials to match colors correctly (Ferster and Hammer, 1966). Two rhesus monkeys matched two objects with 95% accuracy in 25 consecutive responses in 1,199 and 950 trials. Four out of six budgies demonstrated accuracies of at least 95% for 20 consecutive trials and did so in 480 to 1320 trials. Six

pigeons averaged 896.7 trials (range 410-1660) to match two colored stimuli to a level of 80% correct in 20 consecutive trials for two halves of one daily session (Ginsburg, 1955). Three pigeons matched colors to an 80% level taking about 600 to 720 trials (Cumming and Berryman, 1961).

In this study less clear-cut differences between matching and amatching acquisition curves were found for budgies than in data for pigeons. Acquisition curves for matching and amatching in pigeons differed considerably in appearance: the former showing chance behavior followed by steep rises to criterion, correlated with a loss in position preference, and the latter showing much more gradual acquisition and less correlation with position preference behavior (Cumming and Berryman, 1965. The matching curves for budgies fluctuated around chance more than those for pigeons and showed some gradual rises to criterion, and the amatching curves showed both types of rise to criterion. Preferences in matching and amatching were equally strong in this study unlike the findings for pigeons. Budgies demonstrated more color preferences than pigeons in matching and amatching presolution periods (Cumming and Berryman, 1965). Once criterion was achieved in stage I, there was no consistent trend of increase in overall accuracy during the seven sessions of overtraining for either matching or amatching. Pigeons continued to show some increases in accuracy in amatching but did not reach a level comparable to that found in matching tasks, (Cumming and Berryman, 1965).

Budgies showed considerably less transfer of matching to a second problem than rhesus monkeys, who averaged 64 and 85% accuracy on their first 25 trials (Weinstein, 1945), and slightly less than

pigeons, one showing immediate transfer, two others taking 240 to 720 trials to reach 80% accuracy (a savings of 52% for these two) (Ginsburg, 1955) and one showing 75% accuracy on the second day (Cumming and Berryman, 1961). The strength of backward associations on day 1 of Stage II was greater than that reported for pigeons (Gray, 1966).

Conclusions

The primary difference found between matching and amatching was the increase in presolution accuracy in the second matching problem compared to the level in the first matching problem.

Strong evidence for associative symmetry was found in the amatching group, A_1.

Budgerigars proved to be useful as subjects in this study, performing matching and amatching tasks at speeds and at levels of accuracy within the ranges found for chimpanzees, rhesus monkeys and pigeons.

A configuration explanation predicted the increased presolution accuracy in the second problem for matching. A central associative explanation accounted well for the obtained associative symmetry but predicted greater negative transfer than was obtained in A_2. Greater differences in favor of matching in acquisition and transfer would have been expected from both of these approaches.

The coding hypothesis accurately predicted little difference in matching and amatching in acquisition but could not account for the transfer results obtained.

An extended coding hypothesis incorporated the useful features of the central associative explanation into the original coding hypoth-

esis and yielded more satisfactory explanations of the results obtained in this study. Limitations are still found with this explanation, such as in predicting the coding response substitutions that will take place in a new situation.

REFERENCES

Asch, S. E. & Ebenholtz, M. The principle of associative symmetry. Proceedings of the American Philosophical Society, 1962, 106, 135-163.

Bitterman, M. E. & Wodinsky, J. The solution of oddity and non-oddity problems by the rat. American Journal of Psychology, 1953, 66, 137-140.

Brockway, B. F. The effects of nest-entrance positions and male vocalizations on reproduction in budgerigars. The Living Bird. First Annual of the Cornell Laboratory of Ornithology, 1962, 93-101.

_____. Social influences on reproductive physiology and ethology of budgerigars (Melopsittacus undulatus). Animal Behavior, 1964(a), 12, 493-501.

_____. Ethological studies of the budgerigar: reproductive behavior. Behaviour, 1964(b), 23, 294-324.

_____. Stimulation of ovarian development and egg-laying by male courtship vocalization in budgerigars (Melopsittacus undulatus). Animal Behavior, 1965, 13, 575-578.

_____. Social and experiential influences of nextbox-oriented behavior and gonadal activity of female budgerigars (Melopsittacus undulatus Shaw). Behaviour, 1967, 29, 65-82.

Cogan, D., Inmam, S. & Gambrel, M. Discrimination in parakeets (Melopsittacus undulatus) as a function of age. The Psychological Record, 1971, 21, 117-120.

Cohen, L. R. Generalization during acquisition, extinction, and transfer of matching with an adjustable comparison. Journal of the Experimental Analysis of Behavior, 1969, 12 (3), 463-474.

Cumming, W. W. & Berryman, R. Some data on matching in the pigeon. Journal of the Experimental Analysis of Behavior, 1961, 4, 281-284.

_____ & _____. The complex discriminated operant: Studies of matching-to-sample and related problems. In D. Mostofsky (Ed.), Stimulus Generalization. Stanford, Calif.: Stanford University Press, 1965, 284-330.

_____, _____ & Cohen, L.R. Acquisition and transfer of zero-delay matching. Psychological Reports, 1965, 17, 435-445.

Dawson, B. V. & Foss, B. M. Observational learning in budgerigars. Animal Behavior, 1965, 13, 470-474.

Dunn, O. J. Multiple comparisons among means. Journal of the American Statistical Association, 1961, 56, 52-64.

Eckerman, D. A., Lanson, R. N. & Cumming, W. W. Acquisition and maintenance of matching without a required observing response. Journal of the Experimental Analysis of Behavior, 1968, 11, 435-441.

Ekstrand, B. R. Backward associations. Psychological Bulletin, 1966, 65(1), 50-64.

Ellis, H. C. The Transfer of Learning. New York: The MacMillan Company, 1965.

Ferster, C. B. & Hammer, C. E., Jr. Synthesizing the components of arithmetic behavior. In W. K. Honig (Ed.), Operant Behavior, Areas of Research and Application. New York: Appleton-Century-Crofts, 1966, 634-676.

Gallup, G. G., Jr. & Capper, S. A. Preference for mirror-image stimulation in finches (Passer domesticus domesticus) and parakeets (Melopsittacus undulatus). Animal Behavior, 1970, 18, 621-624.

Ginsburg, N. Matching from sample in pigeons. Unpublished doctoral dissertation, University of Chicago, 1955.

_____. Conditioned vocalization in the budgerigar. Journal of Comparative and Physiological Psychology, 1960, 53(2), 183-186.

_____ & Nilsson, V. Measuring flicker thresholds in the budgerigar. Journal of the Experimental Analysis of Behavior, 1971, 15, 189-192.

Gray, L. Backward association in pigeons. Psychonomic Science, 1966, 4 (9), 333-334.

Gulliksen, H. & Wolfle, D. L. A theory of learning and transfer: I. Psychometrika, 1938, 3, 127-149.

Harlow, H. F. Primate learning. In C. P. Stone (Ed.) Comparative Psychology. New York: Prentice-Hall, 1951, 183-238.

Hilgard, E. R. Methods and procedures in the study of learning. In S. S. Stevens (Ed.), Handbook of Experimental Psychology. New York: Wiley, 1964, 533.

Hoats, D. L. & Gerjuoy, I. R. Associative symmetry with two conditions of perceptual organization. Psychonomic Science, 1966, 4(10), 341-342.

Jackson, W. J. & Pegram, G. V. Comparison of intra-vs. extradimensional transfer of matching by rhesus monkeys. Psychonomic Science, 1970, 19 (3), 162-163.

Kamil, A. C. & Sacks, R. A. Three-configuration matching-to-sample in the pigeon. Journal of the Experimental Analysis of Behavior, 1972, 17, 483-488.

Köhler, W. On the nature of associations. Proceedings of the American Philosophical Society, 1941, 84, 489-502.

Malott, R. W., Malott, M. K. & Svinicki, J. Acquisition of stimulus matching without the use of non-matching stimuli. Psychonomic Science, 1967, 9 (1), 21-22.

Marshall, A. J. (Ed.), Biology and Comparative Physiology of Birds. Vol. II. New York: Academic Press, 1961.

Meltzer, D., Maxey, G. C. & Merkler, N. L. Sequential amatching in the squirrel monkey. Psychological Reports, 1966, 19, 859-867.

Mishkin, M., Prockop, E. S. & Rosvold, H. E. One-trial object-discrimination learning in monkeys with frontal lesions. Journal of Comparative and Physiological Psychology, 1962, 55, 178-181.

Murdock, B. B., Jr. Transfer designs and formulas. Psychological Bulletin, 1957, 54, 313-326.

Nissen, H. W., Blum, J. & Blum, R. A. Analysis of matching behavior in chimpanzees. Journal of Comparative and Physiological Psychology, 1948, 41, 62-74.

Plath, M. Über das Farbenunterschiedungsvermögen des Wellensitticha. Zeitschrift fuer vergleichende Physiologie, 1935, 22, 691-708.

Skinner, B. F. Are theories of learning necessary? Psychological Review, 1950, 57, 193-216.

Tolman, E. & Krechevsky, I. Means-and-readiness and hypothesis. A contribution to comparative psychology. Psychological Review, 1933, 40, 60-70.

Weinstein, B. Matching-from-sample by rhesus monkeys and by children. Journal of Comparative Psychology, 1941, 31, 195-213.

_____. The evolution of intelligent behavior in rhesus monkeys. Genetic Psychology Monographs, 1945, 31, 3-48.

Woodburne, L. S. & Rieke, G. K. Response to symbols by squirrel monkeys. Psychonomic Science, 1966, 5, 429-430.

Wright, D. C., French, G. M. & Riley, D. A. Similarity responding by monkeys in a matching to sample task. Journal of Comparative and Physiological Psychology, 1968, 65 (2), 191-196.

APPENDIX

Table 8. Number of trials for subjects to complete criterion.

Groups	Stages	Subjects					
		1	2	3	4	5	6
M_1	I	460	1280	430			
	II	440	790	280			
M_2	I	360	640	999			
	II	440	280	860			
A_1	I	520	780	1080	750	280	559
	II	80	120	160	156	80	80
A_2	I	400	1320	1000	600	1080	900
	II	700	1320	540	360	360	415
A_3	I	1362	1290	870	690	460	
	II	240	640	470	490	400	
A_4	I	1350	850	1240	780	510	
	II	630	320	760	400	300	

Table 9. Type of presolution preferences displayed by individual subjects.

Groups	Subjects	Stages I	Stages II
M_1	1	Left	Right
	2	Left	Yellow-Right
	3	Right	Yellow
M_2	1	Right	(Left)
	2	Yellow	Green
	3	Right	(Green-Left)
A_1	1	(Yellow-Right-Y.-Left)	
	2	Yellow-Left-(Right)	
	3	Yellow-Right	
	4	Right	
	5	Yellow-Right	
	6	Right	
A_2	1	Right-(Yellow)	(Green-Right-G.)-Left-(Rt.)
	2	Right	Right-Left
	3	Right	Left
	4	Yellow-Right	(Left-Red-Right)
	5	Yellow	(Right-Green)
	6	(Left)-Right-(Left)	(Red)-Right
A_3	1	Left-(Orange-Left)	(Red-Right)
	2	Right	Red
	3	Orange	(Right)
	4	Orange-Right-Left	Red
	5	Right	Red
A_4	1	Right	Right-(Red-Left)
	2	Right-(Orange-Violet)	(Red)-Green
	3	Right-Orange-Right	Left-(Green-L.-G.)
	4	Right	Red-(Right-R.-Left-Green)
	5	Right	Red

Preferences are in the order displayed during presolution for at least two consecutive days. Moderate preferences, 50 to 70%, are in parentheses.

Table 10. Average accuracy during overtraining for individual subjects.

Subjects	M_1	M_2	A_1	A_2	A_3	A_4
1	16.57	17.43	18.43	17.43	17.29	17.43
2	18.71	16.86	18.00	16.43	16.14	16.86
3	16.71	17.14	18.57	18.71	16.43	16.57
4			17.43	19.00	16.86	16.14
5			17.14	18.29	16.43	16.00
6			19.00	19.43		

Table 11. Average accuracy per one-quarter blocks of acquisition.

	Stages							
	I				II			
	Blocks				Blocks			
	1	2	3	4	1	2	3	4
M	9.09	9.61	11.37	11.76	11.69	12.80	14.28	12.87
A_1	11.07	10.65	12.03	12.36				
A_2	9.88	9.86	10.46	12.16	9.76	10.92	11.62	13.04
A_c	9.81	10.17	10.85	11.93	9.52	10.24	11.04	12.96

Table 12. Accuracy in final 20 trials for day I in stage II.

Subjects	M_1	M_2	A_1	A_2	A_3	A_4
1	10	11	18	10	11	9
2	9	9	14	9	9	4
3	11	11	14	9	11	4
4			16	9	9	12
5			18	14	10	12
6			19	7		

Table 13. Percentage savings scores for individual subjects.

Subject	M_1	M_2	A_1	A_2	A_3	A_4
1	4	-22	85	-75	82	53
2	38	56	85	0	50	62
3	35	14	85	46	46	39
4			79	40	29	49
5			71	67	13	41
6			86	54		

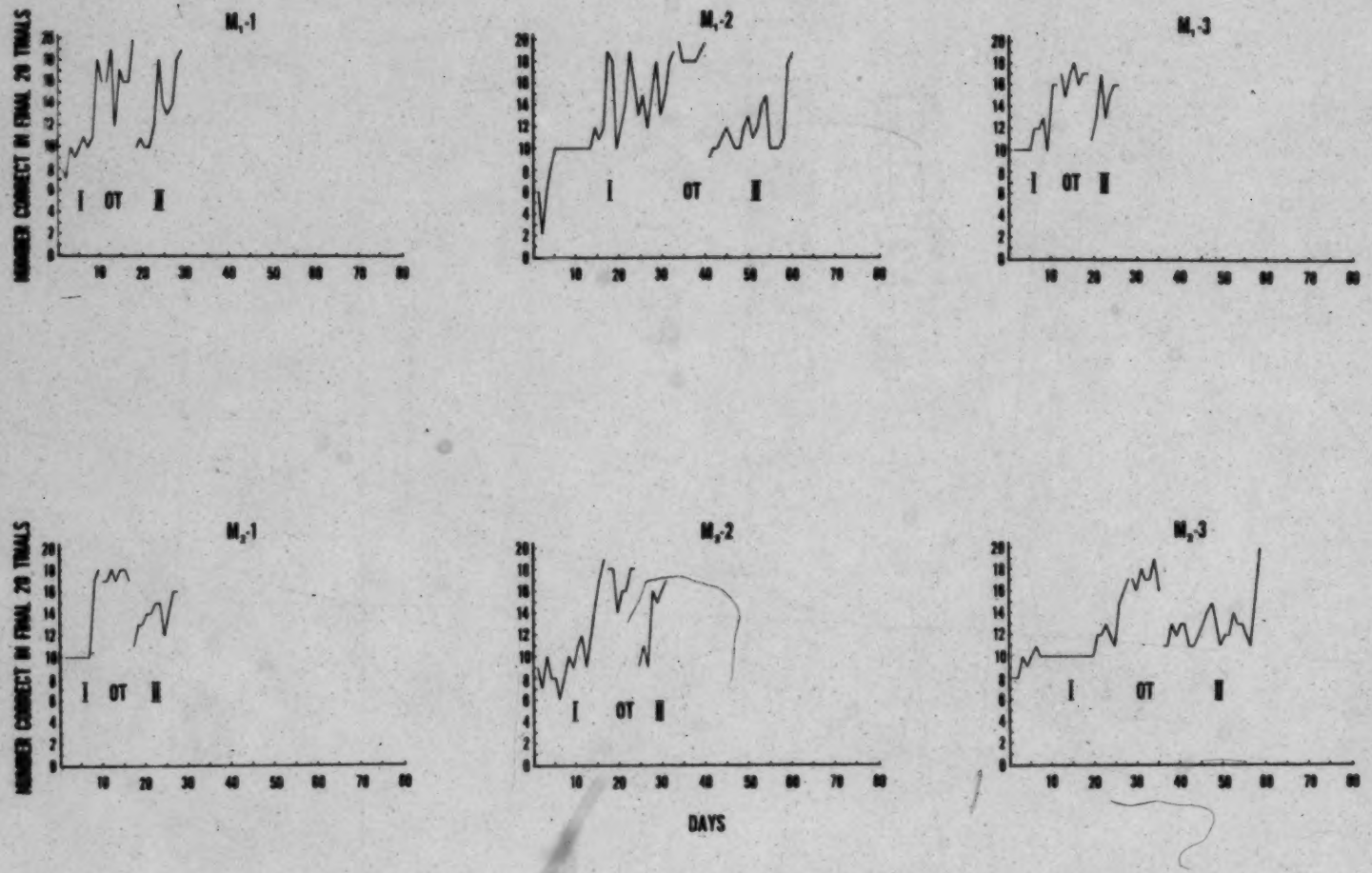


Figure 2. Accuracy of responding during learning stages (I and II) and overtraining (OT) for matching groups M_1 and M_2.

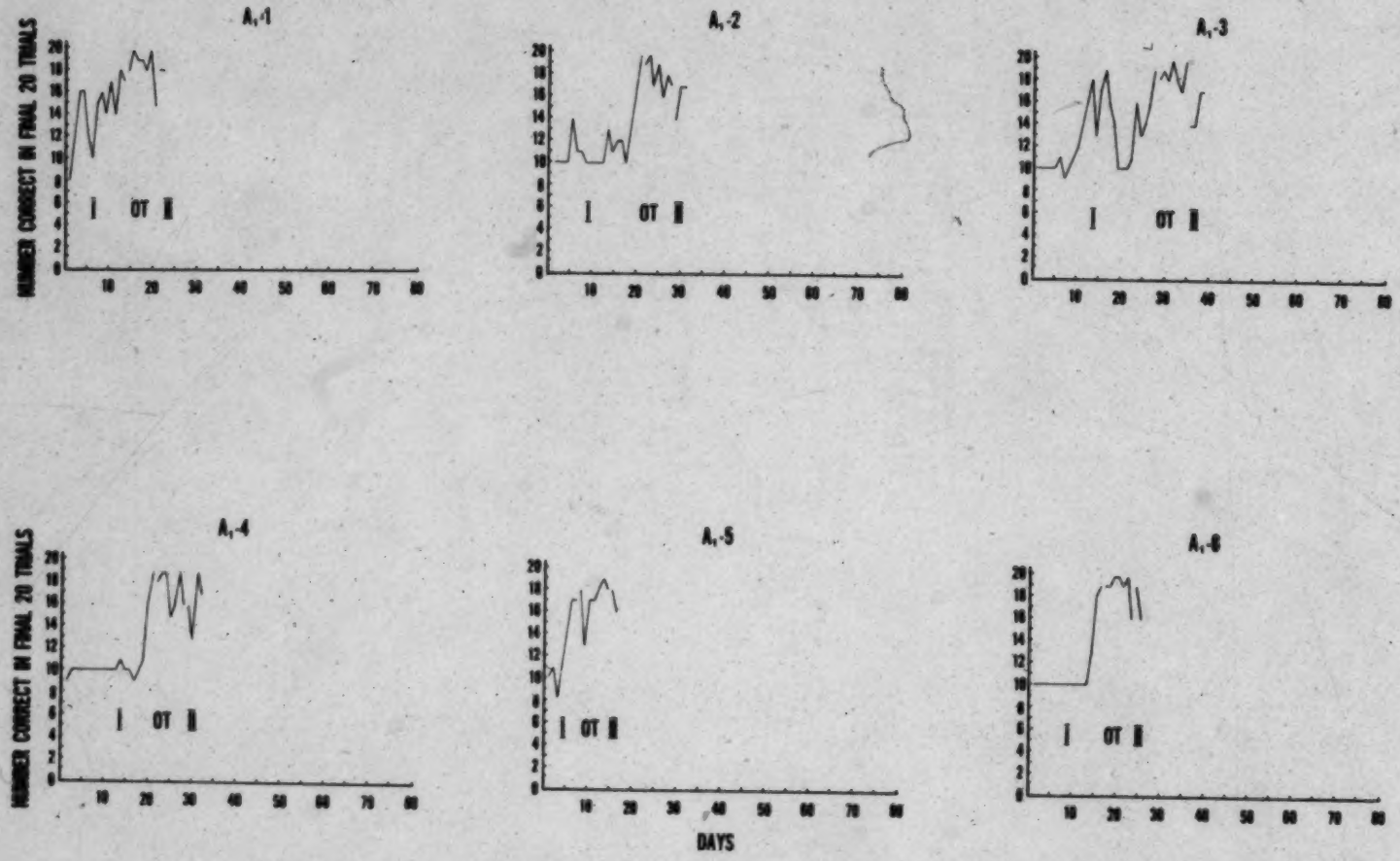


Figure 3. Accuracy of responding during learning stages (I and II) and overtraining (OT) for amatching group A_1.

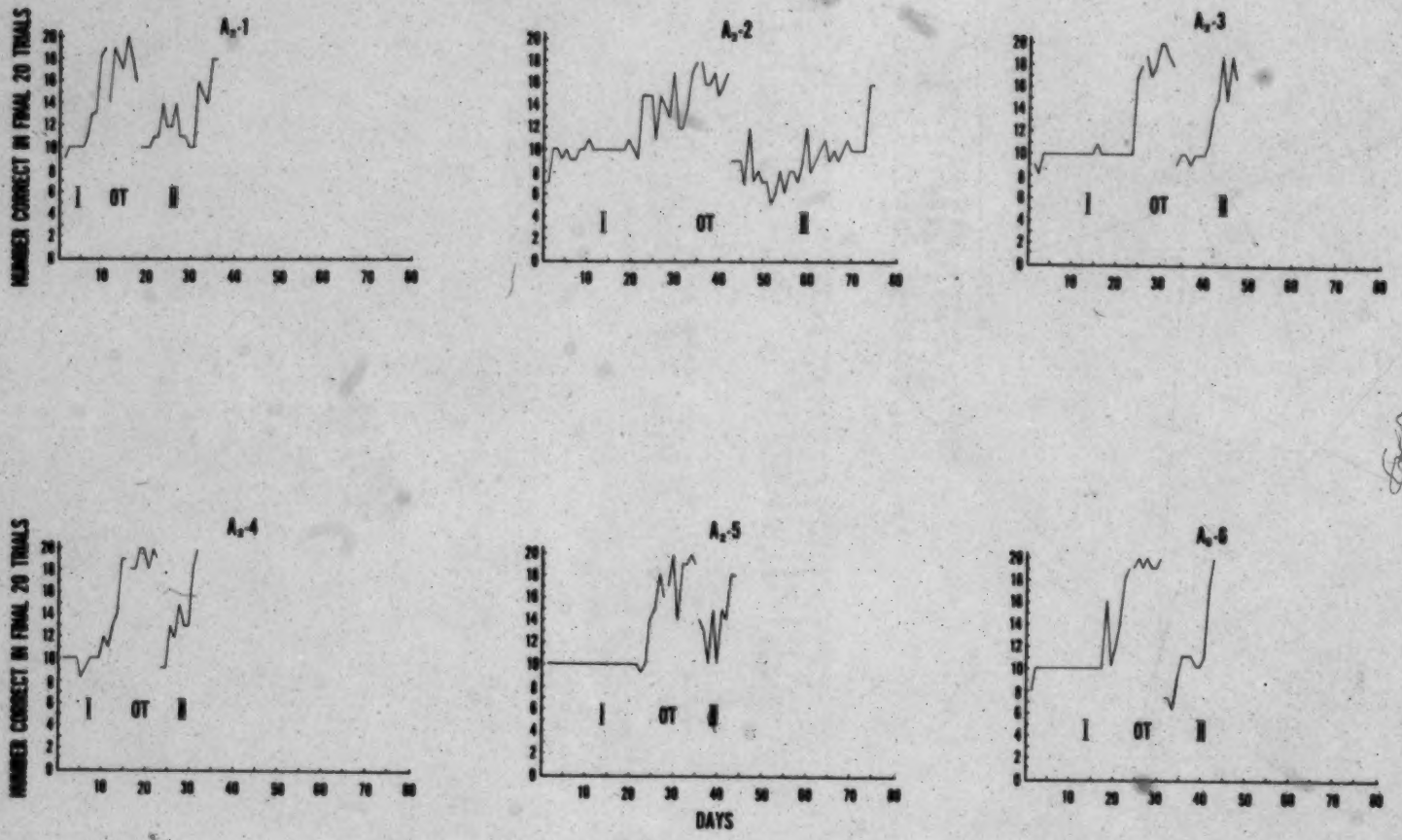


Figure 4. Accuracy of responding during learning stages (I and II) and overtraining (OT) for amatching group A_2.

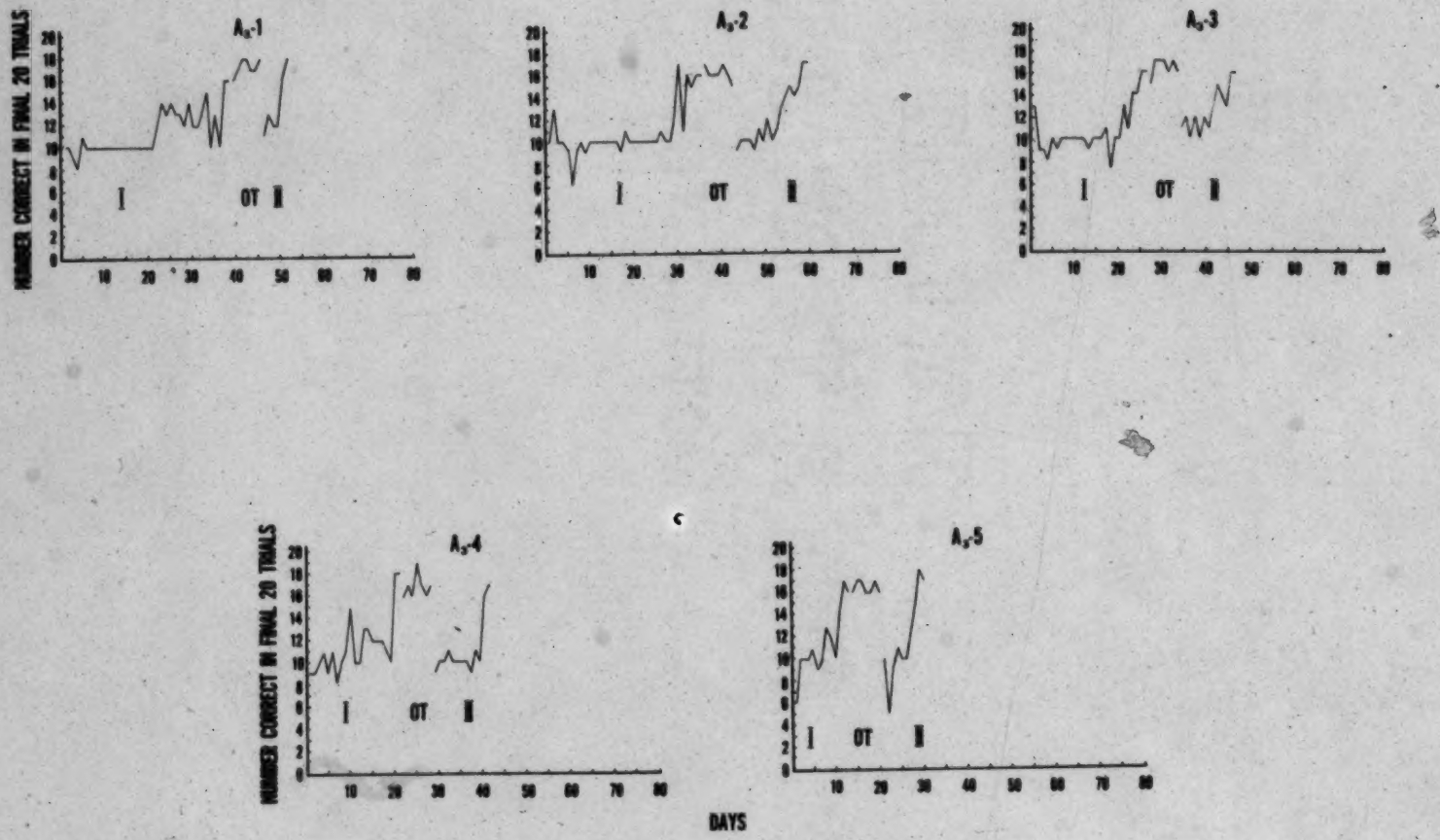


Figure 5. Accuracy of responding during learning stages (I and II) and overtraining (OT) for amatching group A_3.

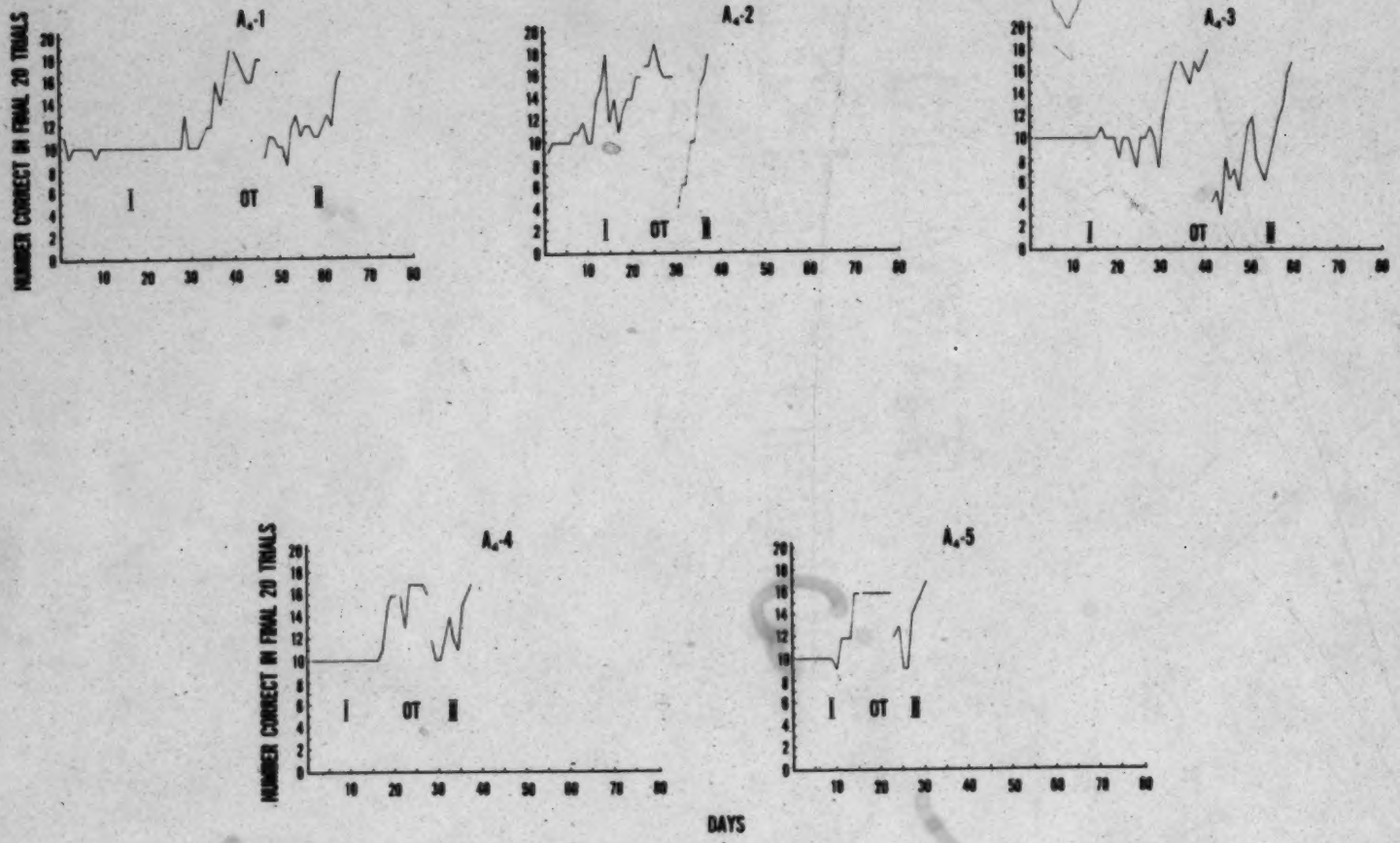


Figure 6. Accuracy of responding during learning stages (I and II) and overtraining (OT) for amatching group A_4.

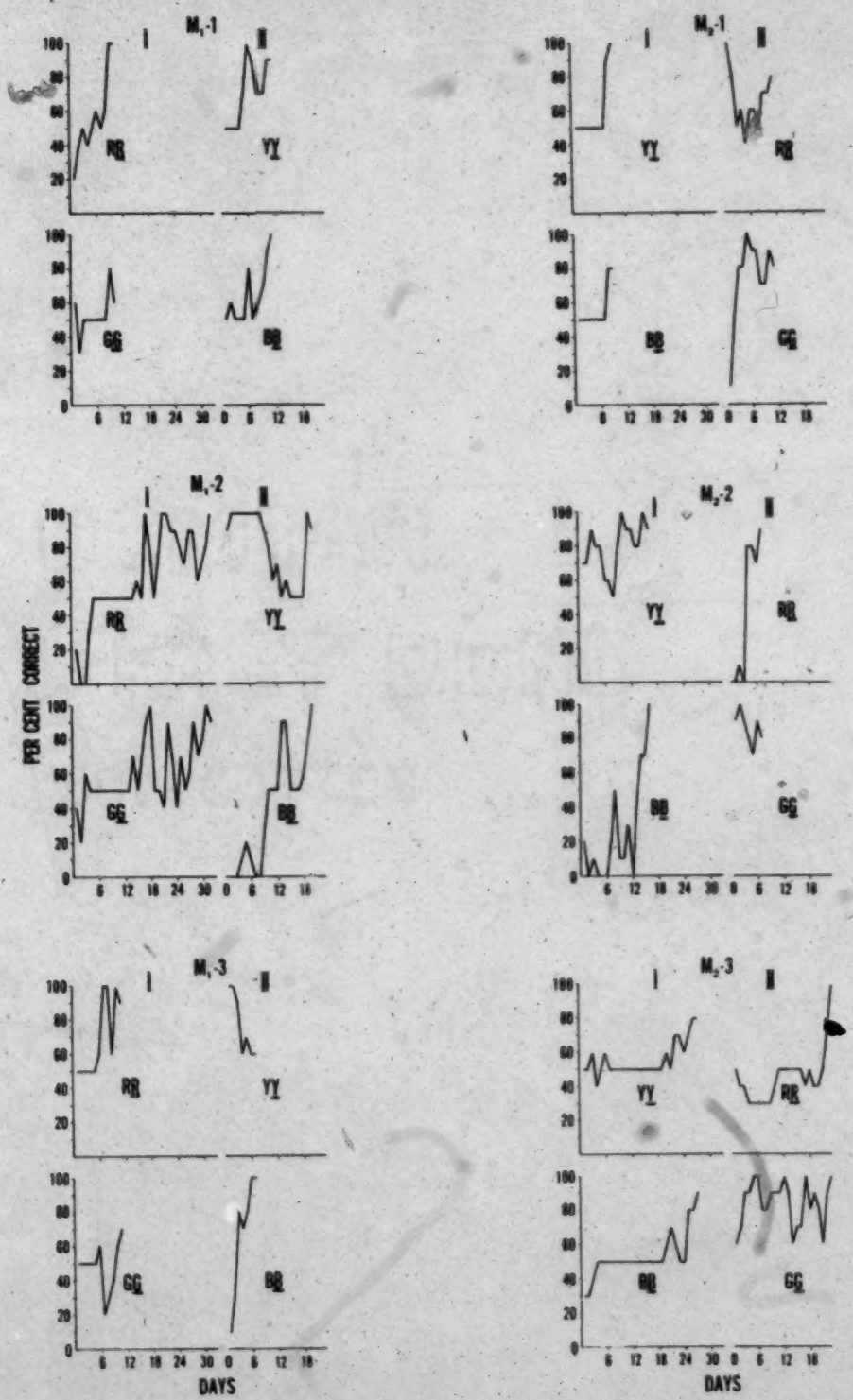


Figure 7. Accuracy of matching ST and CO^+ stimuli (CO^+ underlined) in stages I and II for matching M_1 and M_2.

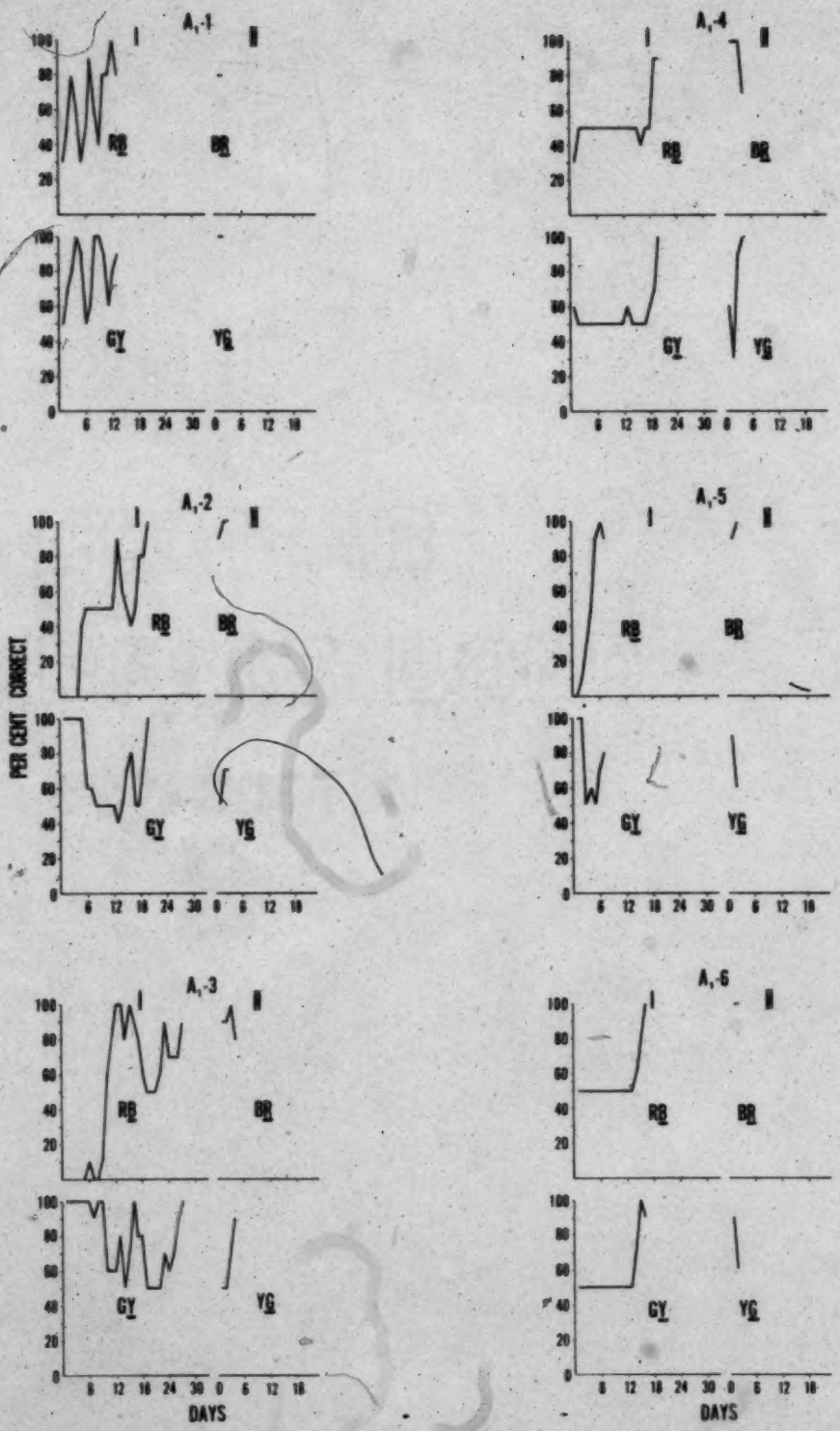


Figure 8. Accuracy of amatching ST and CO^+ stimuli (CO^+ underlined) in stages I and II for amatching group A_1.

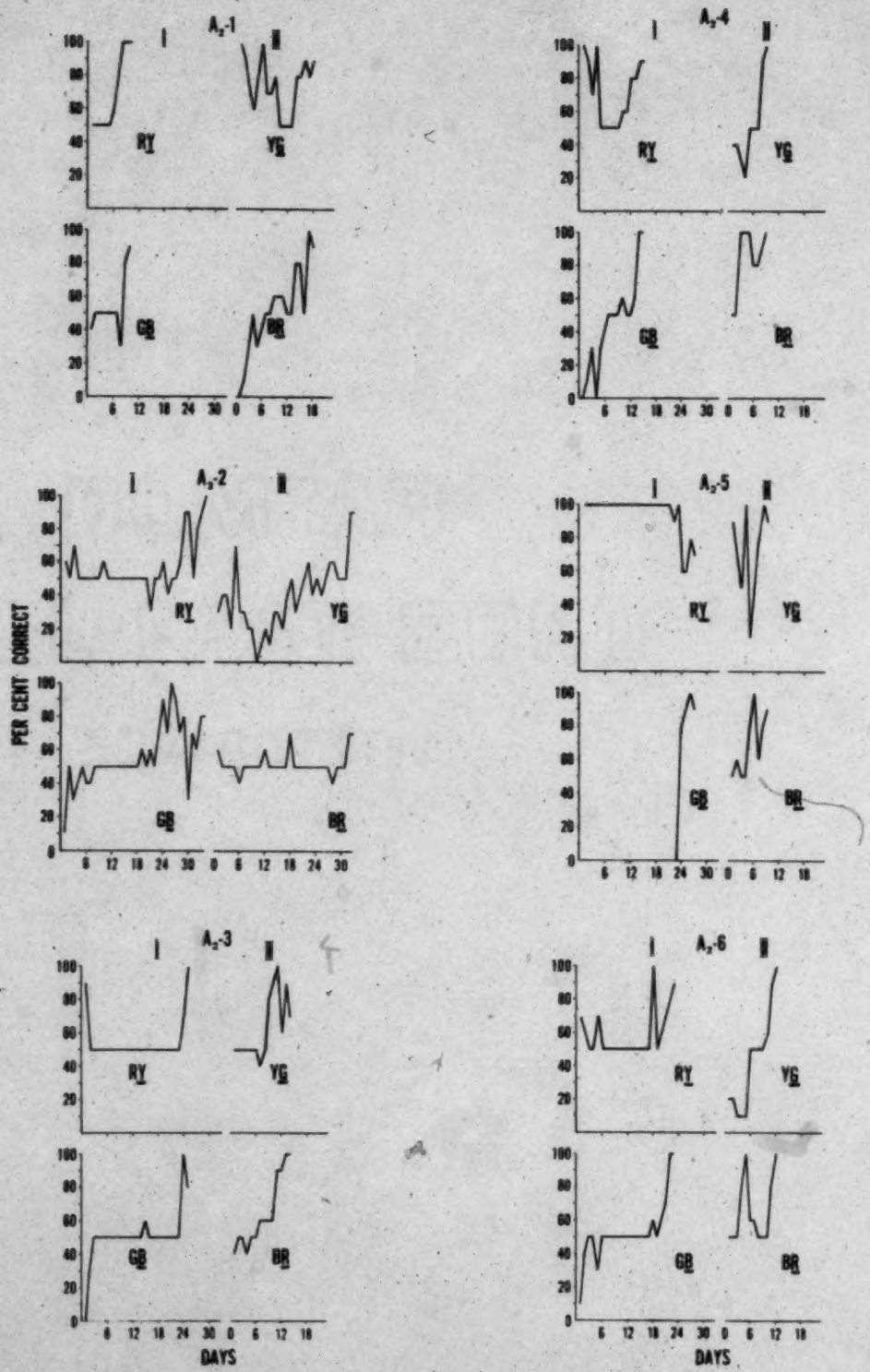


Figure 9. Accuracy of amatching ST and CO^+ stimuli (CO^+ underlined) in stages I and II for amatching group A_2.

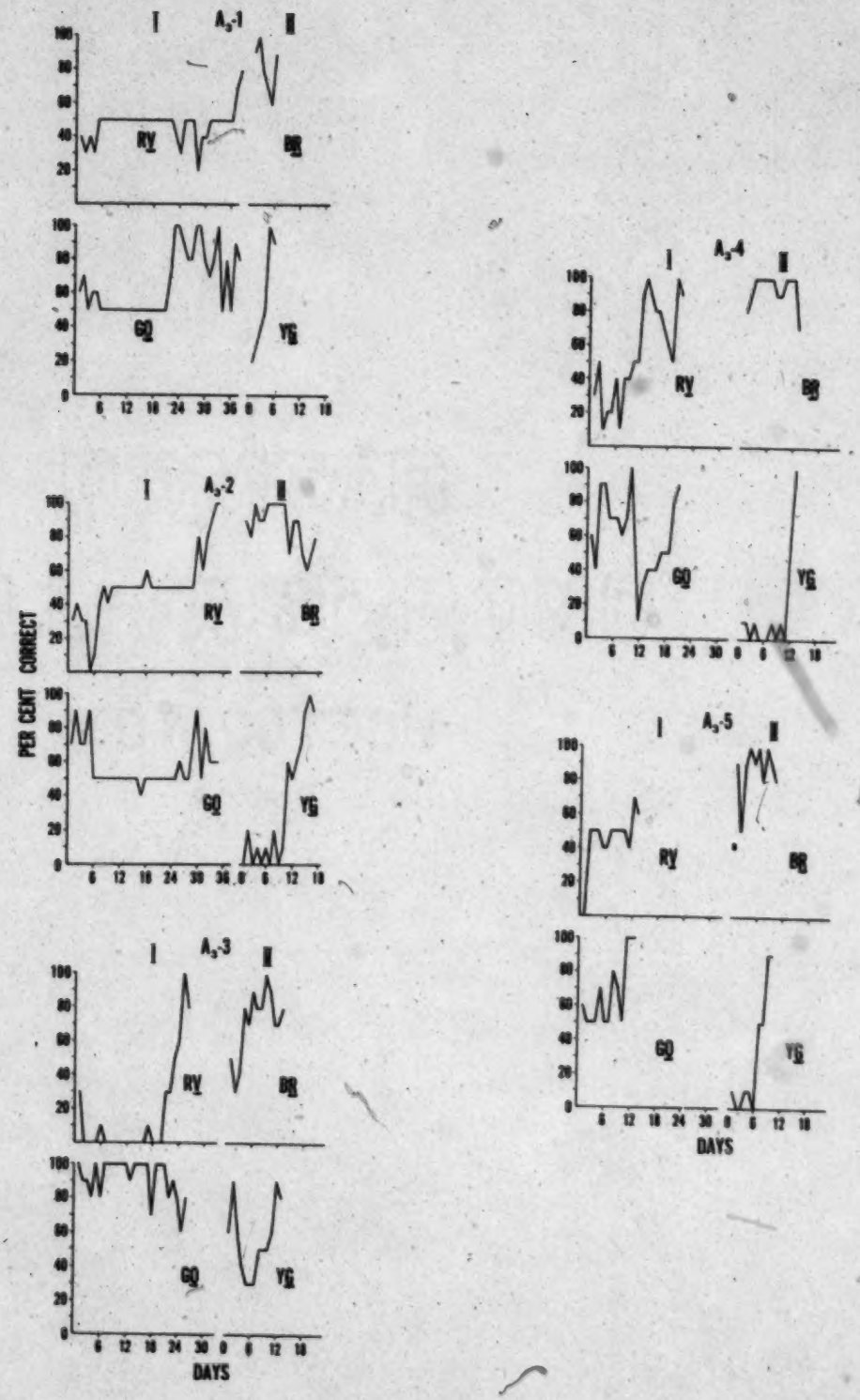


Figure 10. Accuracy of amatching ST and CO^+ stimuli (CO^+ underlined) in stages I and II for amatching group A_3.

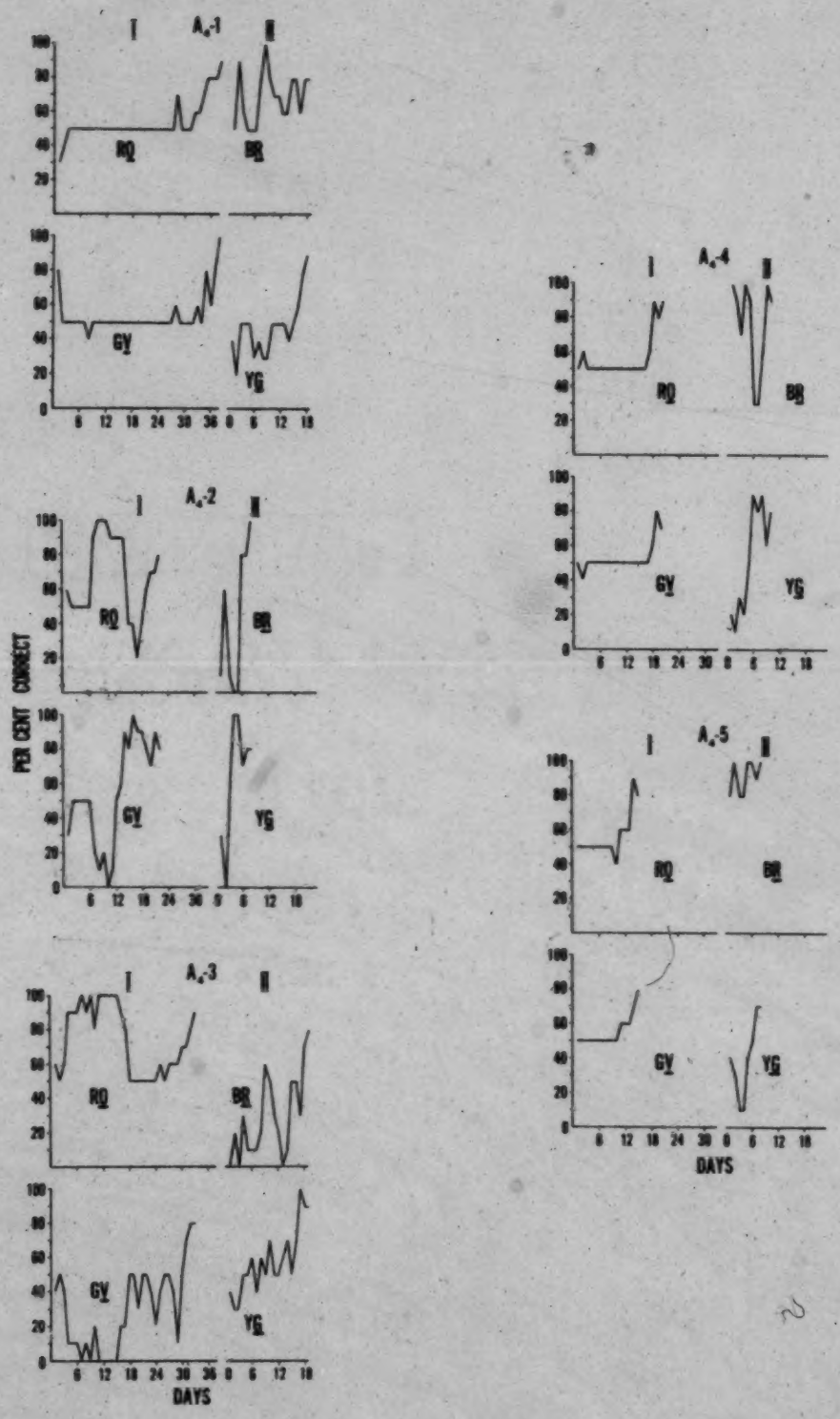


Figure 11. Accuracy of amatching ST and CO^+ stimuli (CO^+ underlined) in stages I and II for amatching group A_4.

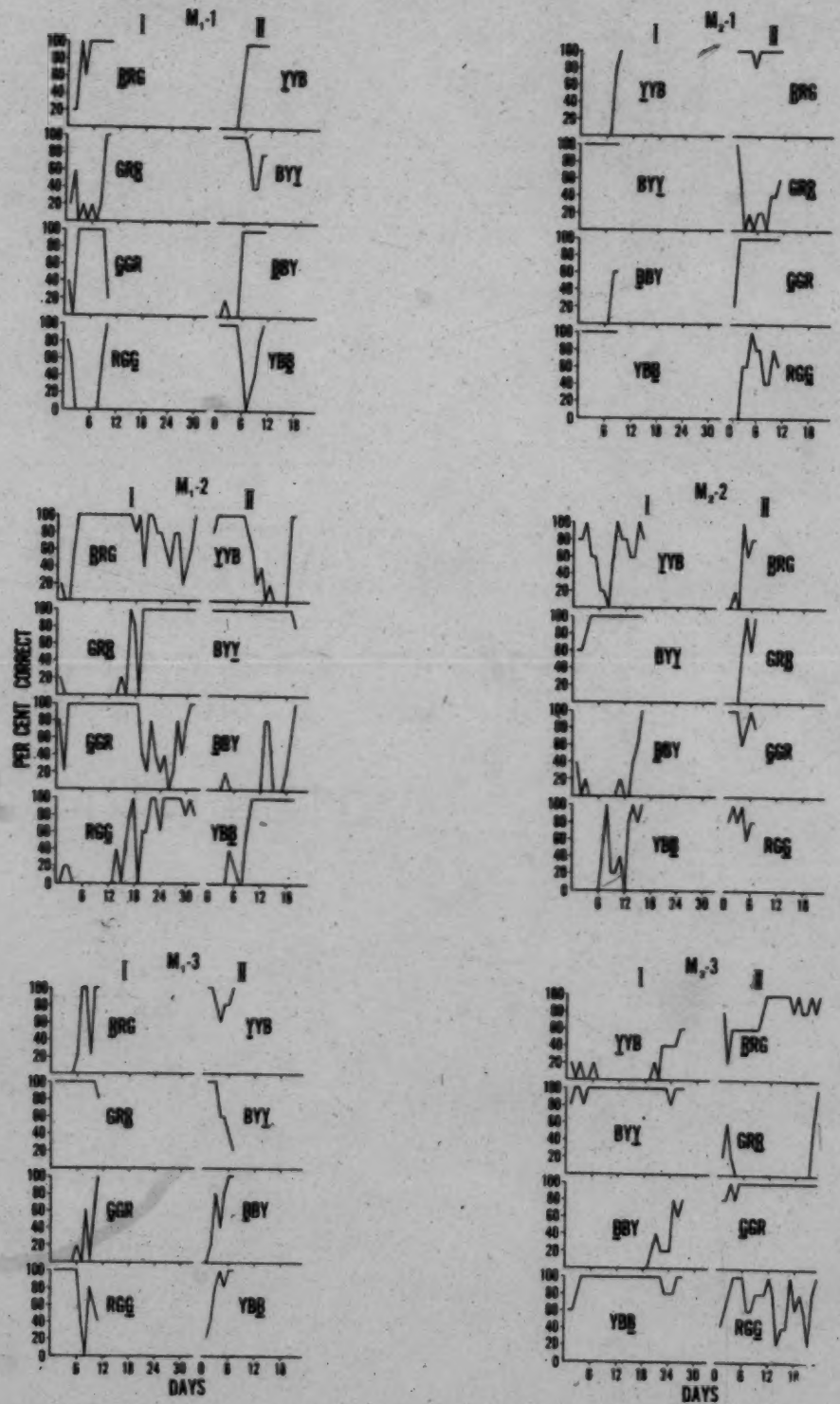


Figure 12. Accuracy of responding to stimulus configurations (CO^+ underlined) in stages I and II for matching groups M_1 and M_2.

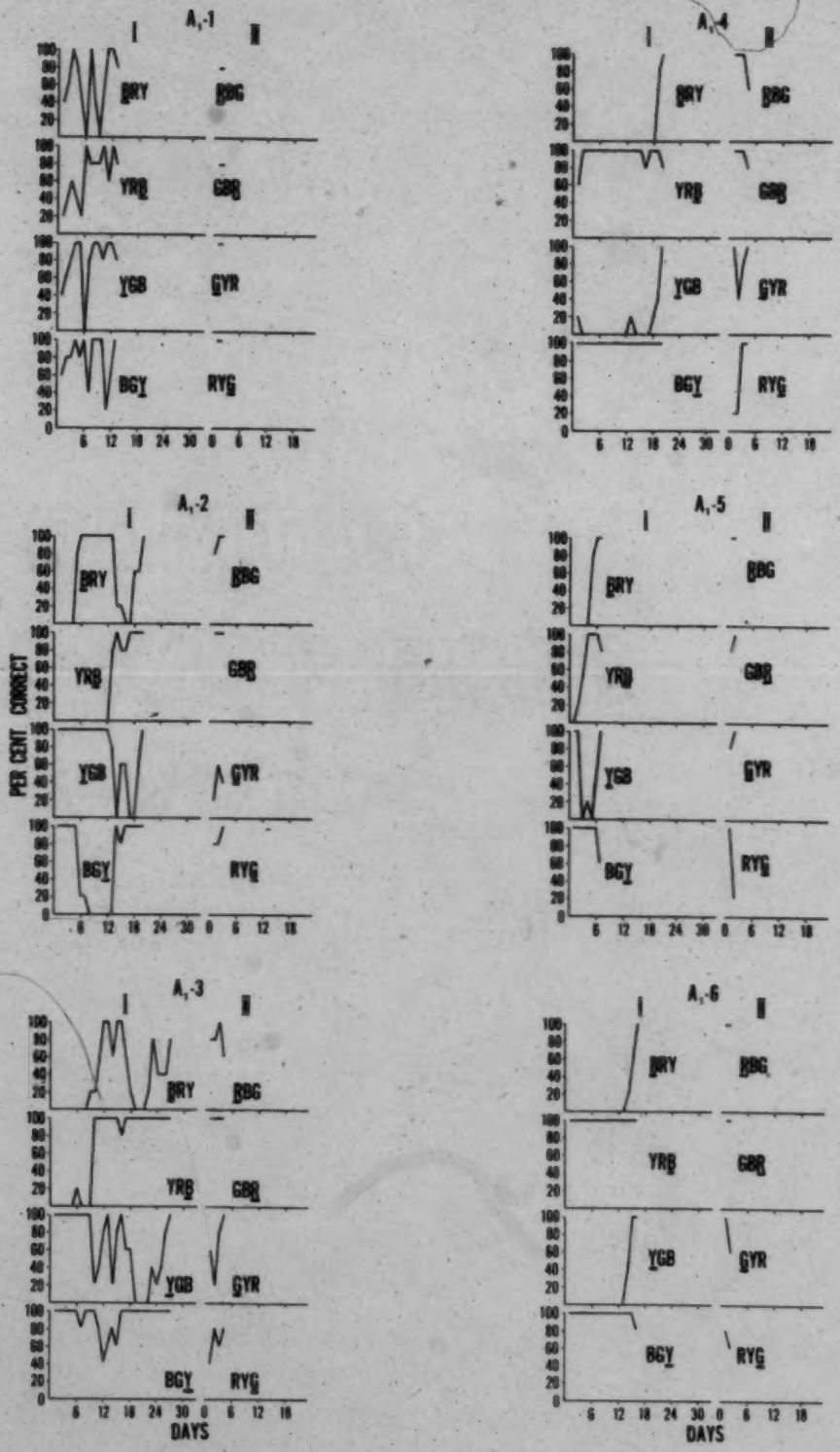


Figure 13. Accuracy of responding to stimulus configurations (CO^+ underlined) in stages I and II for amatching group A_1.

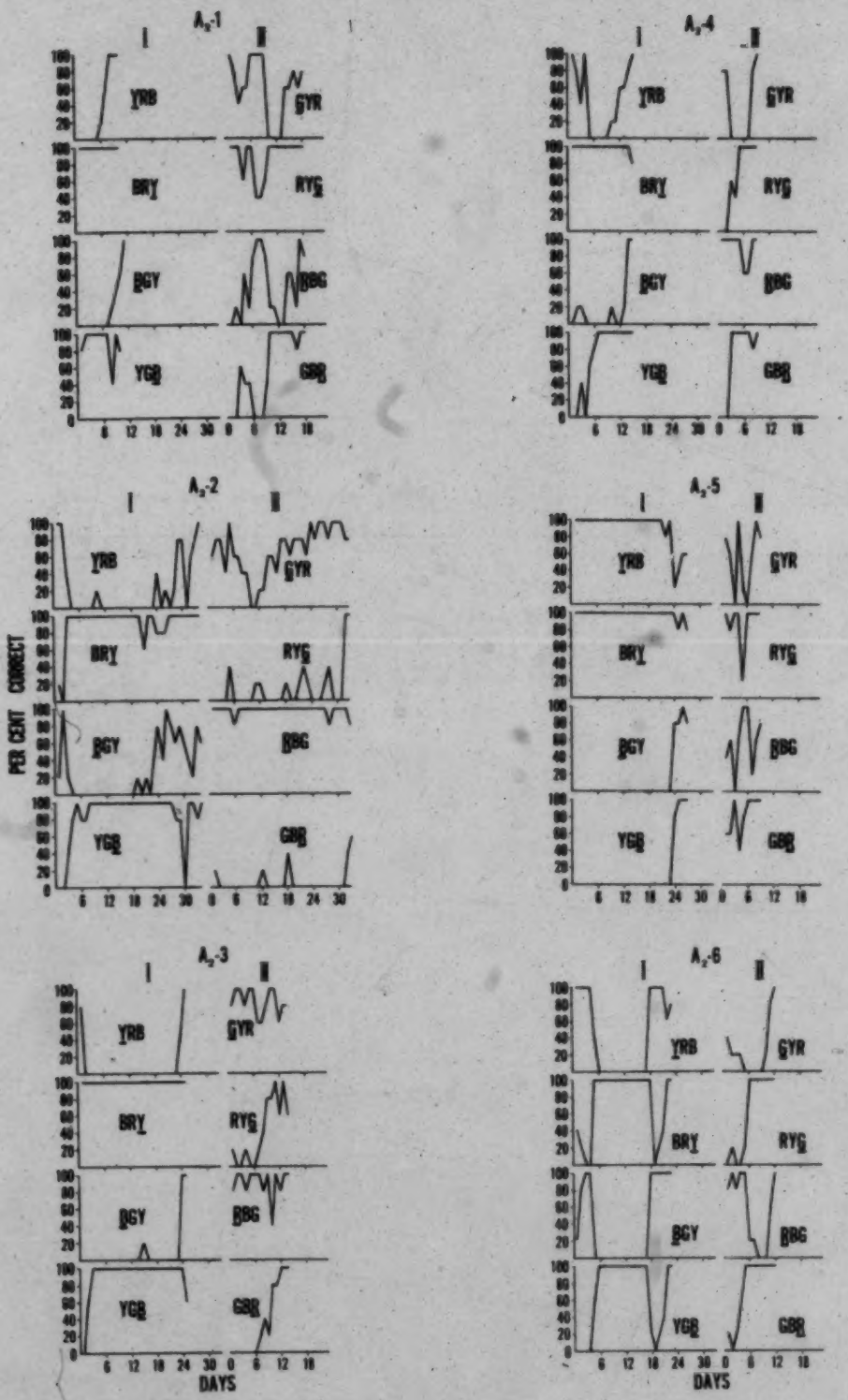


Figure 14. Accuracy of responding to stimulus configurations (CO^{+} underlined) in stages I and II for amatching group A_2.

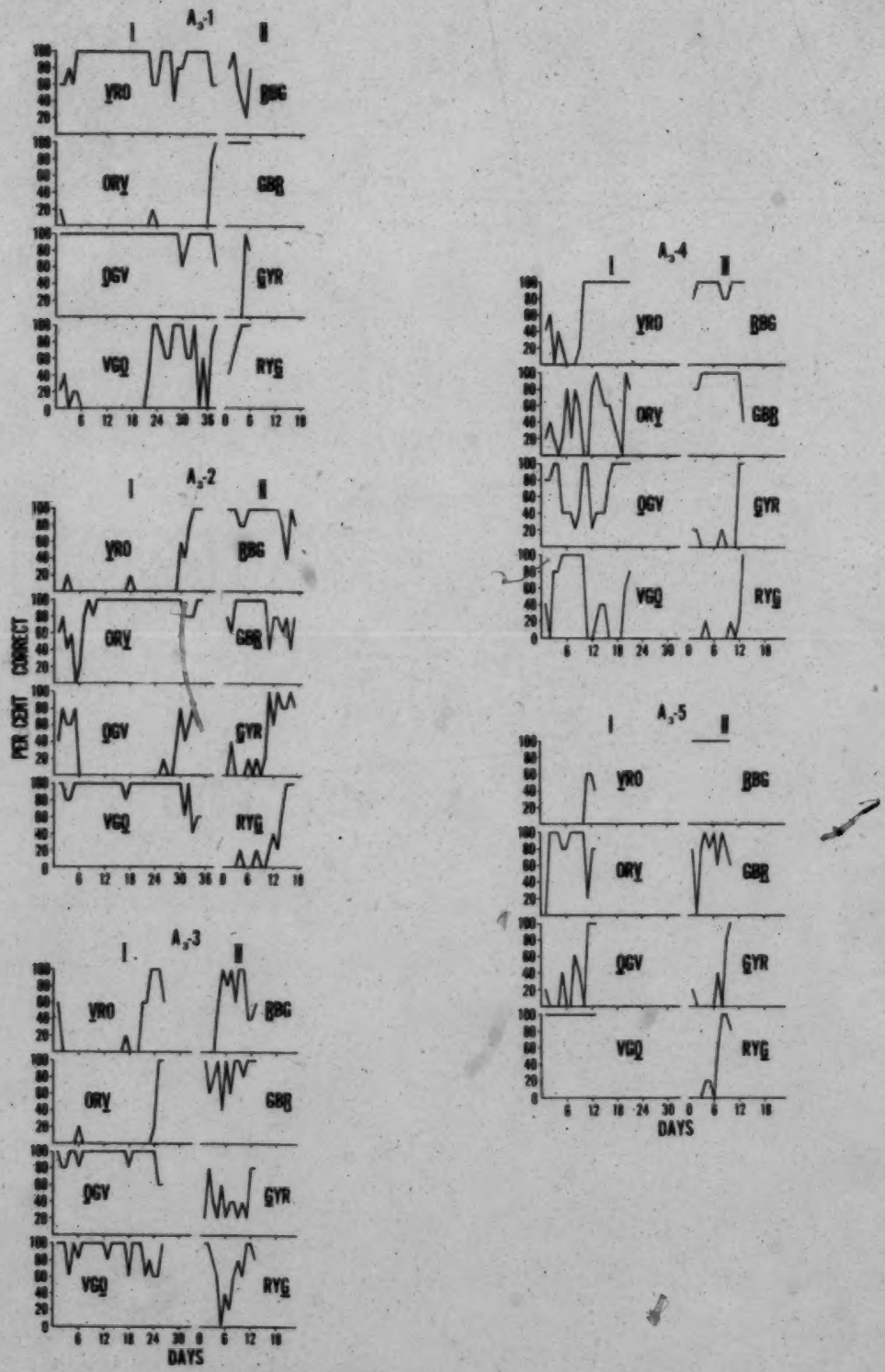


Figure 15. Accuracy of responding to stimulus configurations (CO^+ underlined) in stages I and II for amatching group A_3.

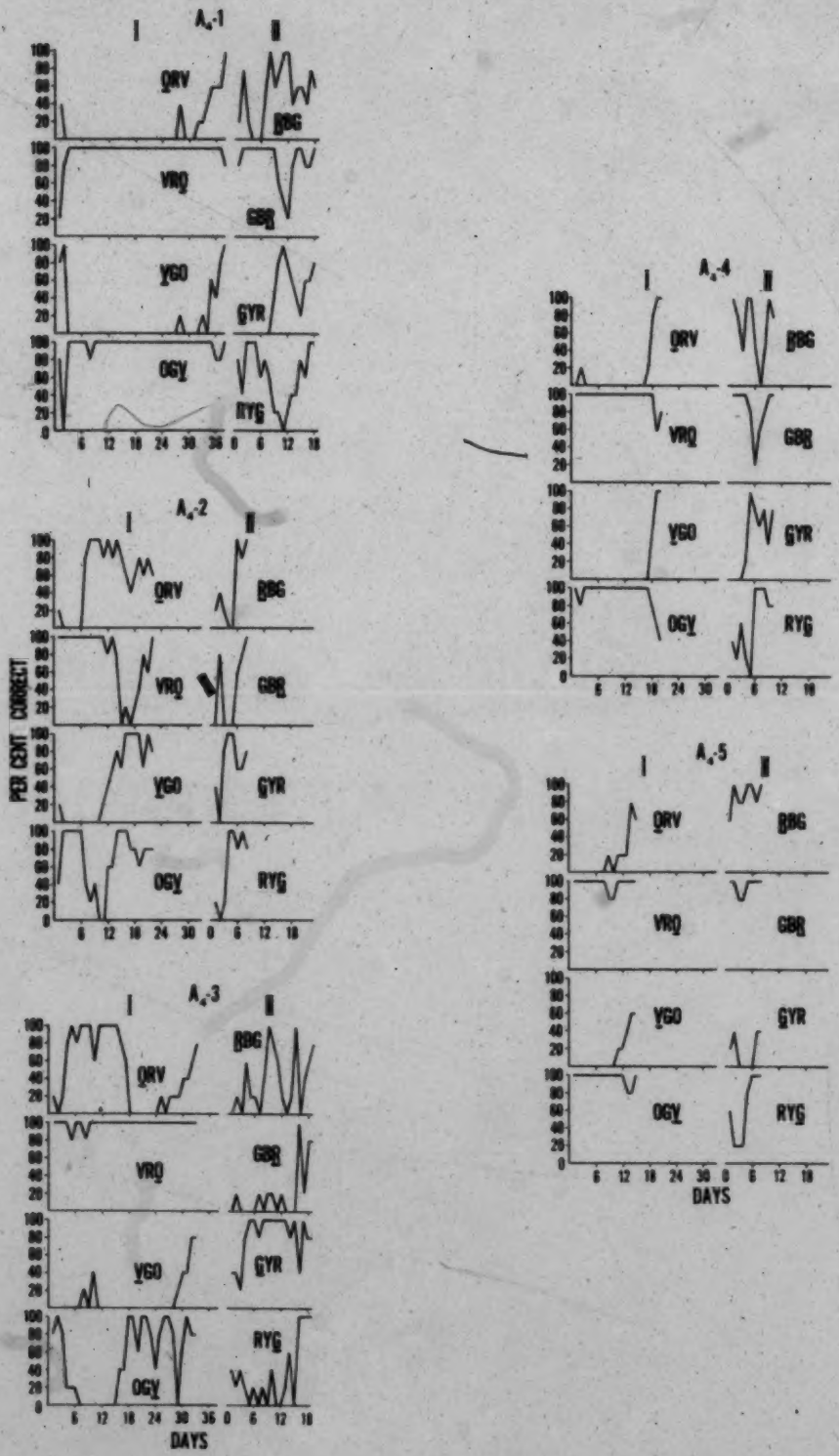


Figure 16. Accuracy of responding to stimulus configurations (CO^+ underlined) in stages I and II for amatching group A_4.

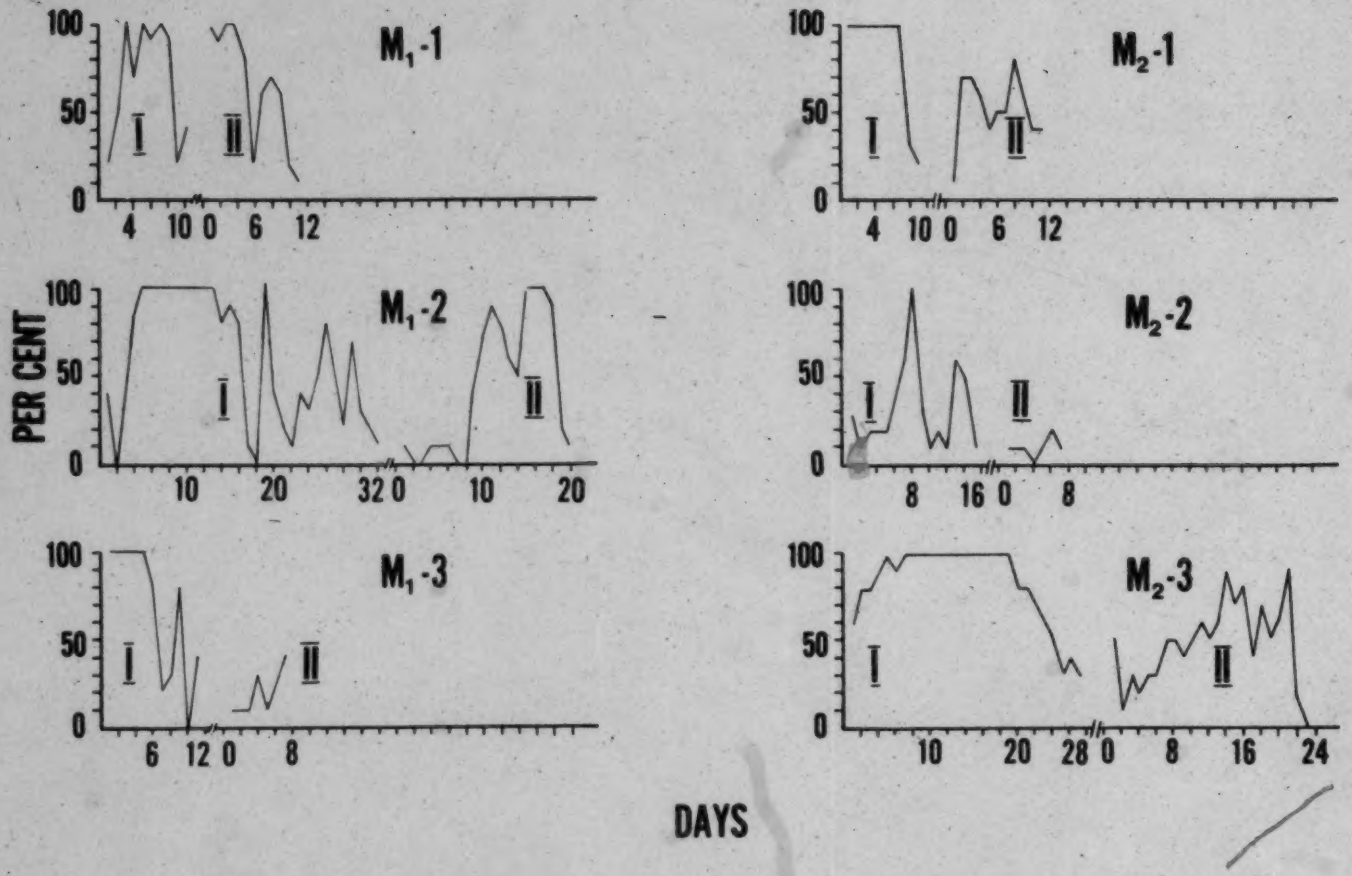


Figure 17. Position preferences in stages I and II for matching groups M_1 and M_2. Equal responding to two positions is a zero preference; exclusive choice of one is 100% preference.

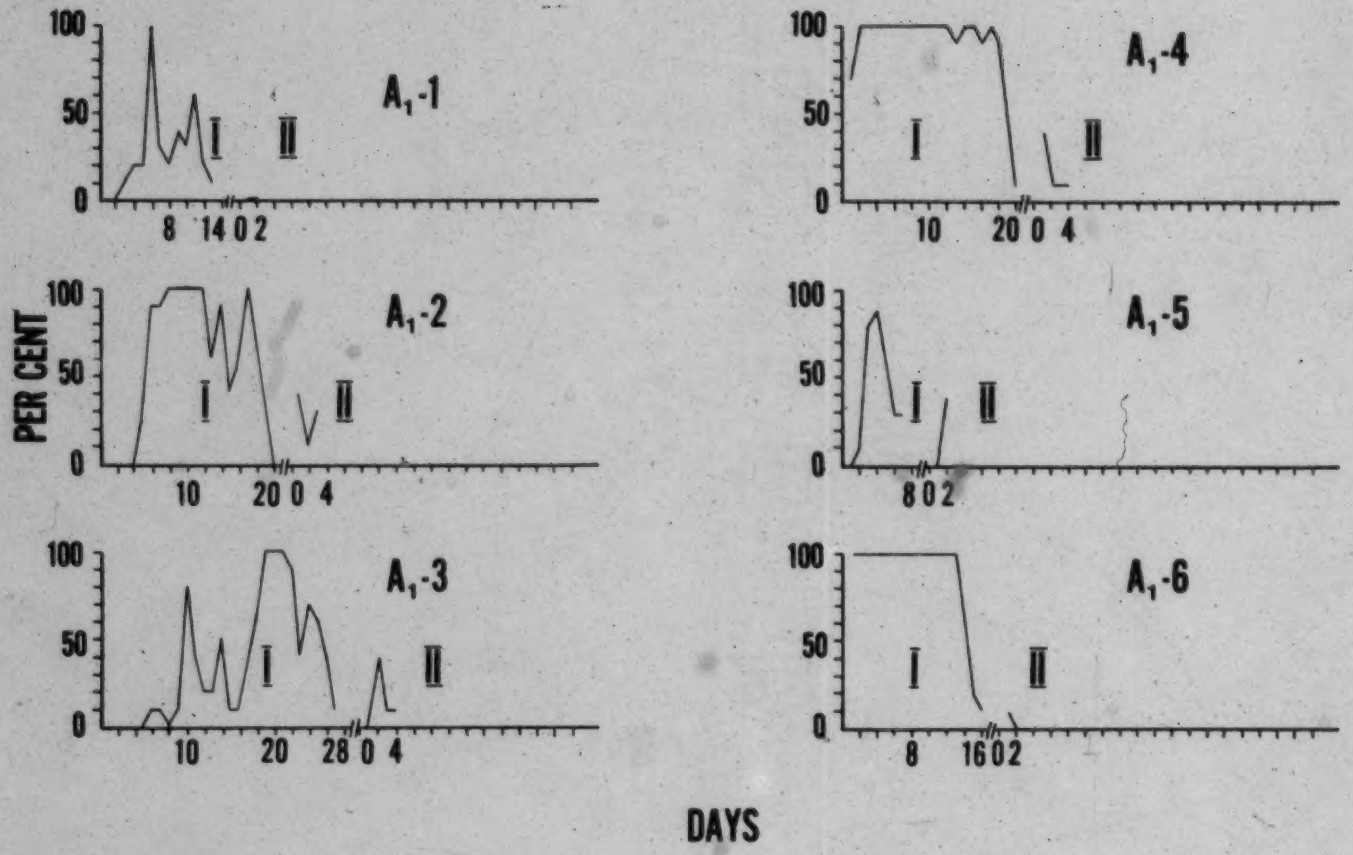


Figure 18. Position preferences in stages I and II for amatching group A_1. Equal responding to two positions is a zero preference; exclusive choice of one is 100% preference.

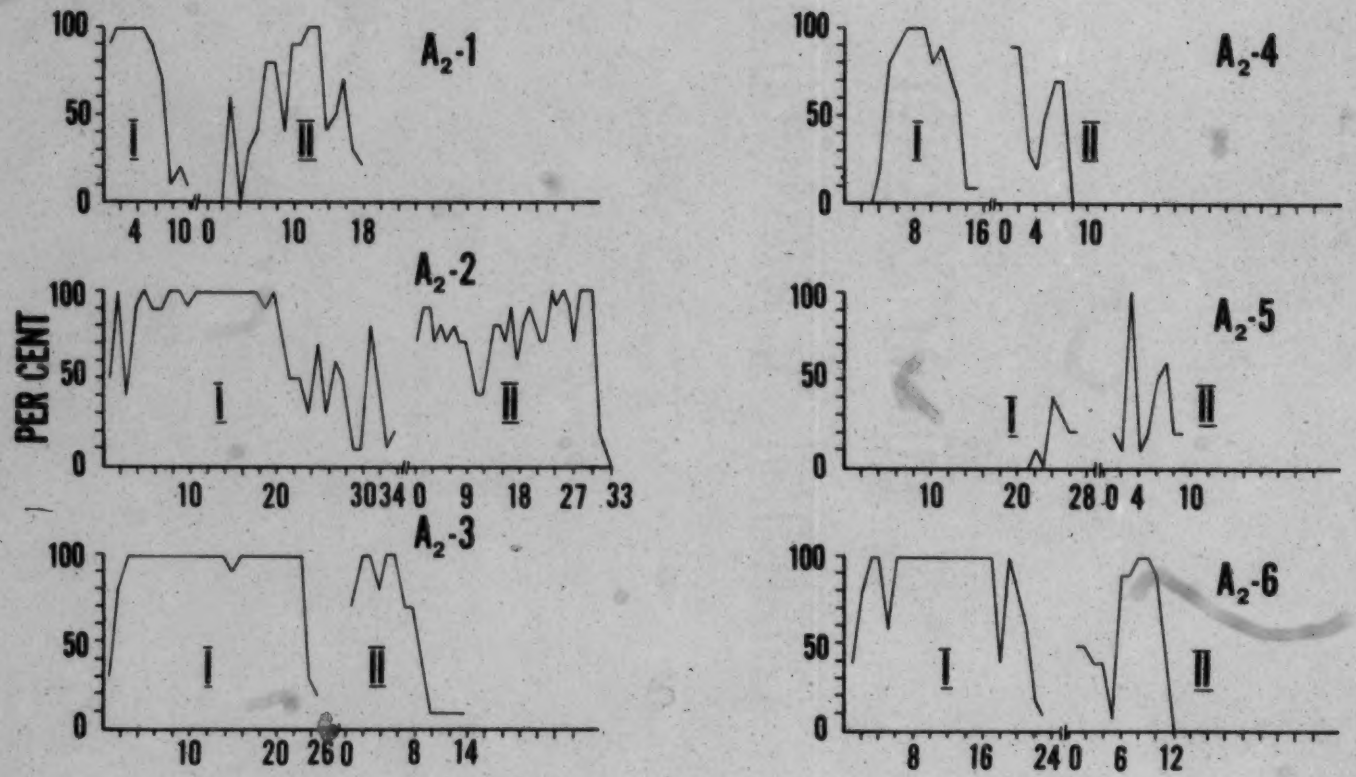


Figure 19. Position preferences in stages I and II for amatching group A_2. Equal responding to two positions is a zero preference; exclusive choice of one is 100% preference.

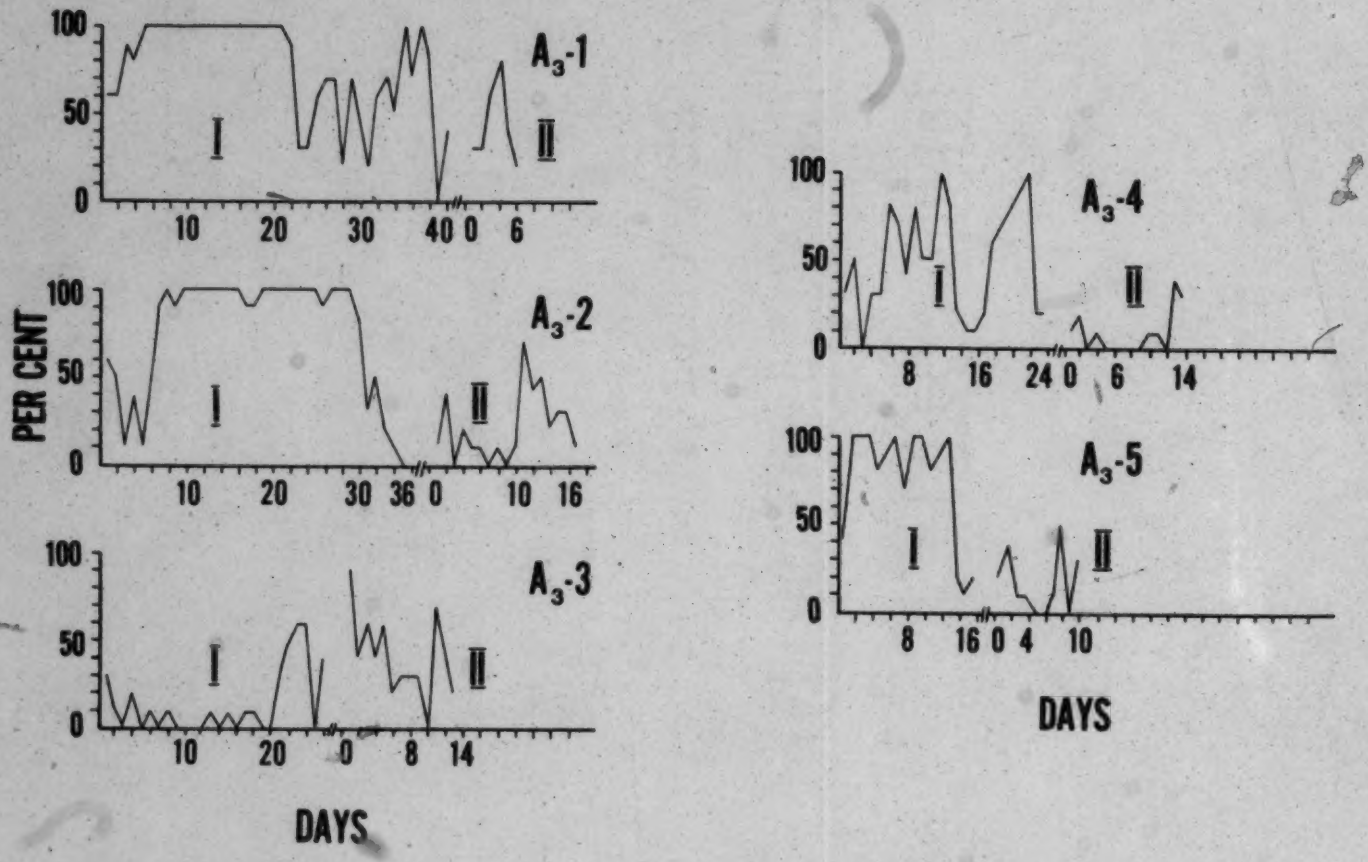


Figure 20. Position preferences in stages I and II for amatching group A_3. Equal responding to two positions is a zero preference; exclusive choice of one is 100% preference.

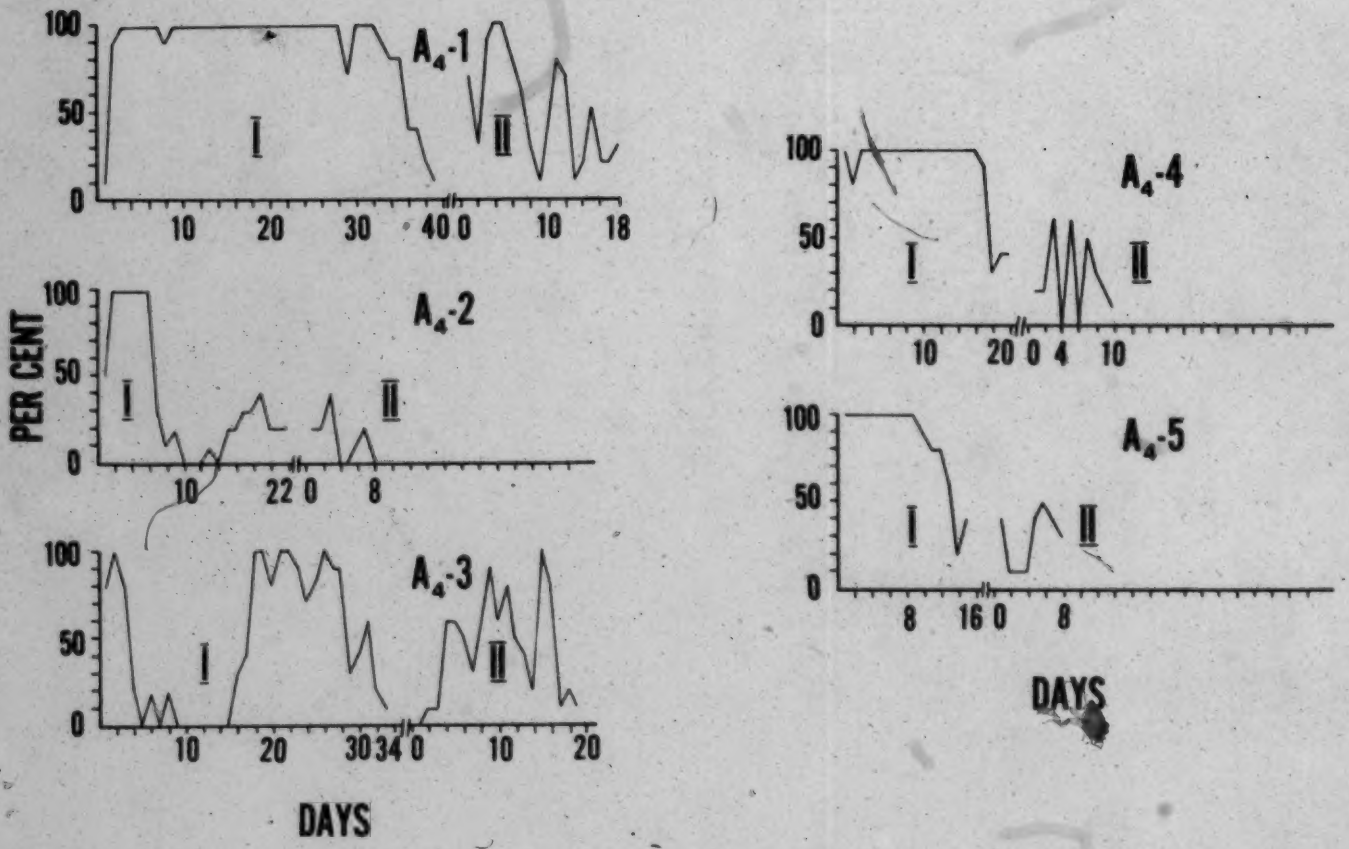


Figure 21. Position preferences in stages I and II for amatching group A_4. Equal responding to two positions is a zero preference; exclusive choice of one is 100% preference.

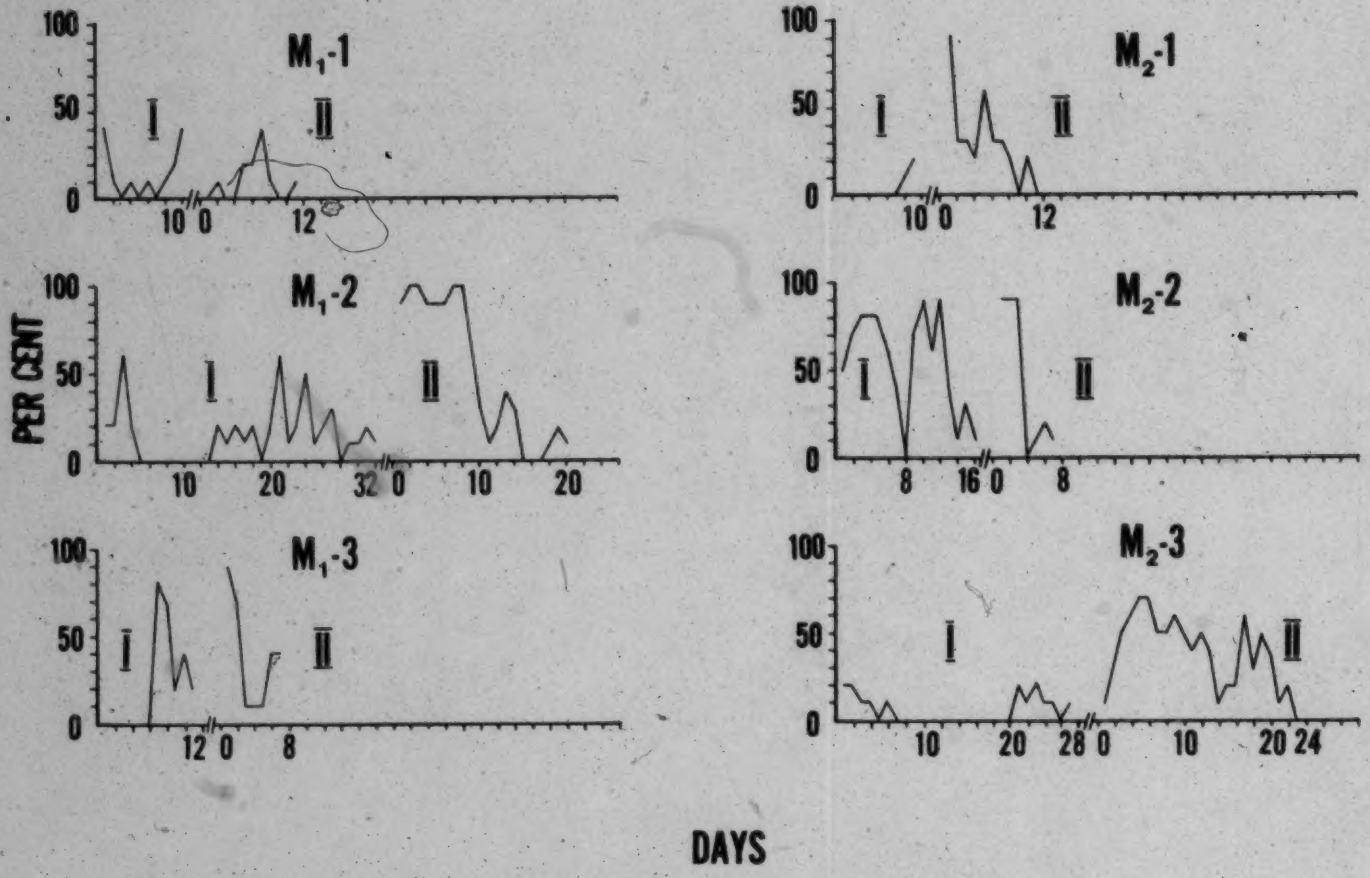


Figure 22. Color preferences in stages I and II for matching groups M_1 and M_2. Equal responding to two CO colors is a zero preference; exclusive choice of one color is 100% preference.

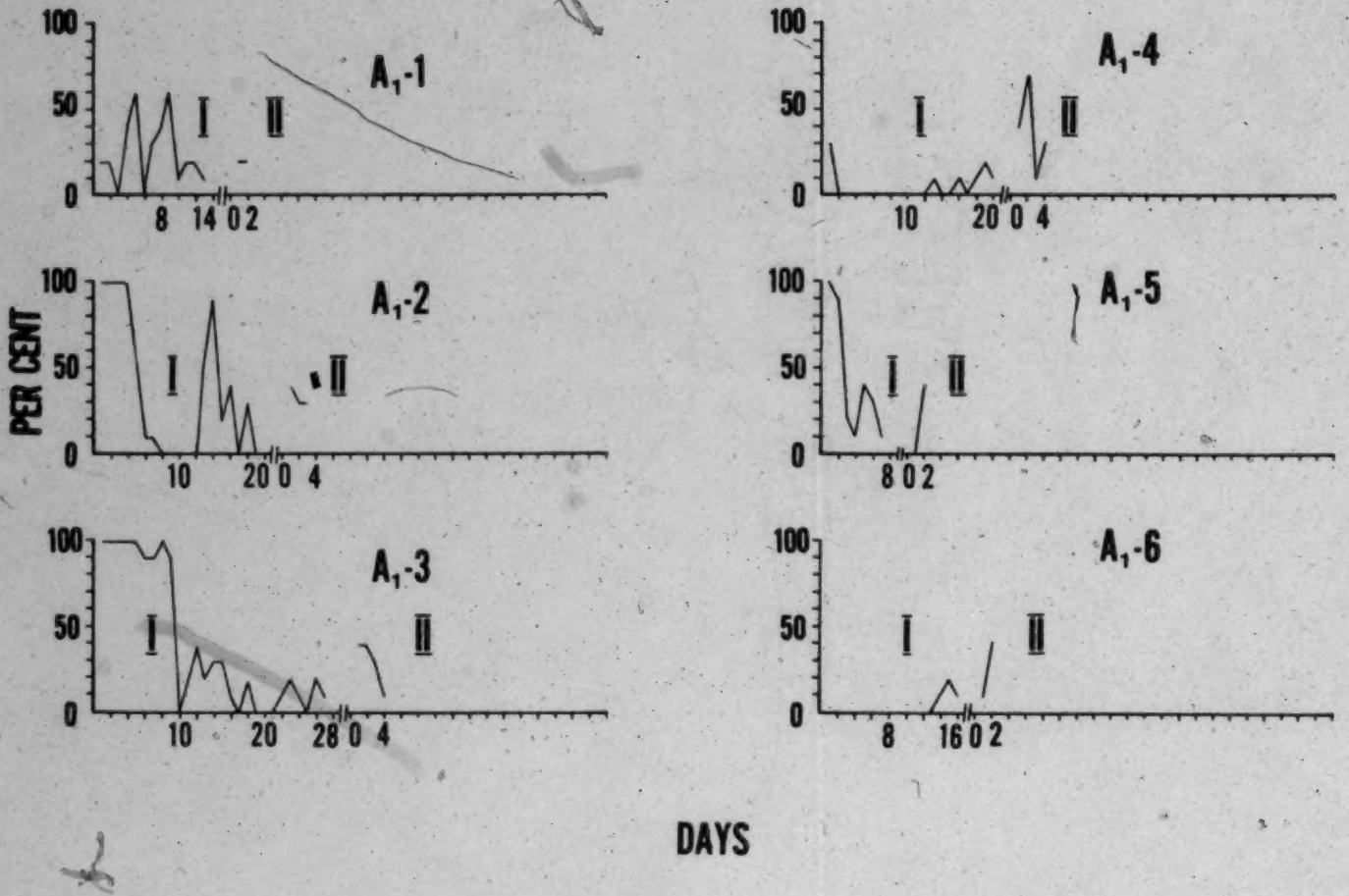


Figure 23. Color preferences in stages I and II for amatching group A_1. Equal responding to two CO colors is a zero preference; exclusive choice of one color is 100% preference.

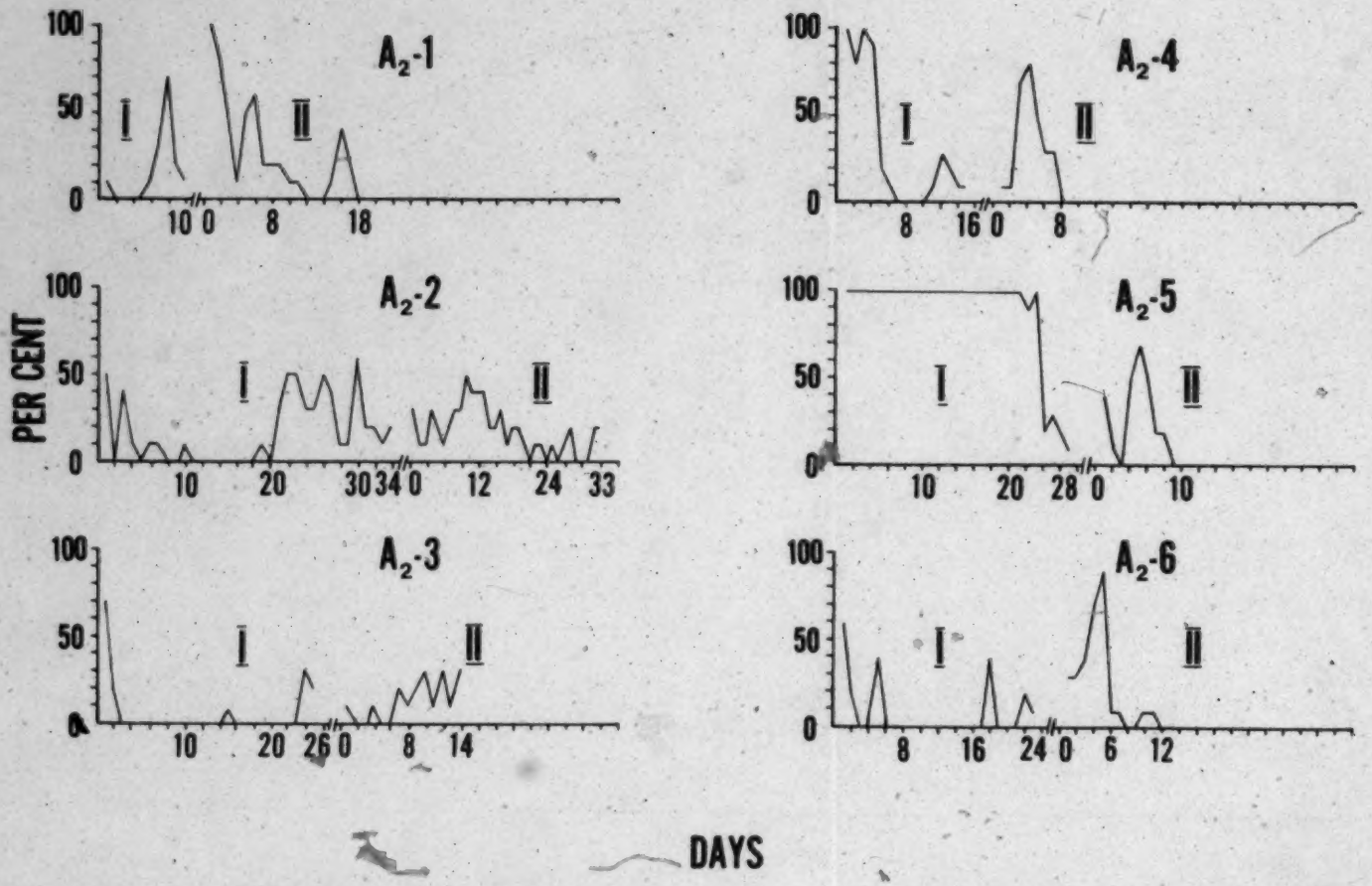


Figure 24. Color preferences in stages I and II for amatching group A_2. Equal responding to two CO colors is a zero preference; exclusive choice of one color is 100% preference.

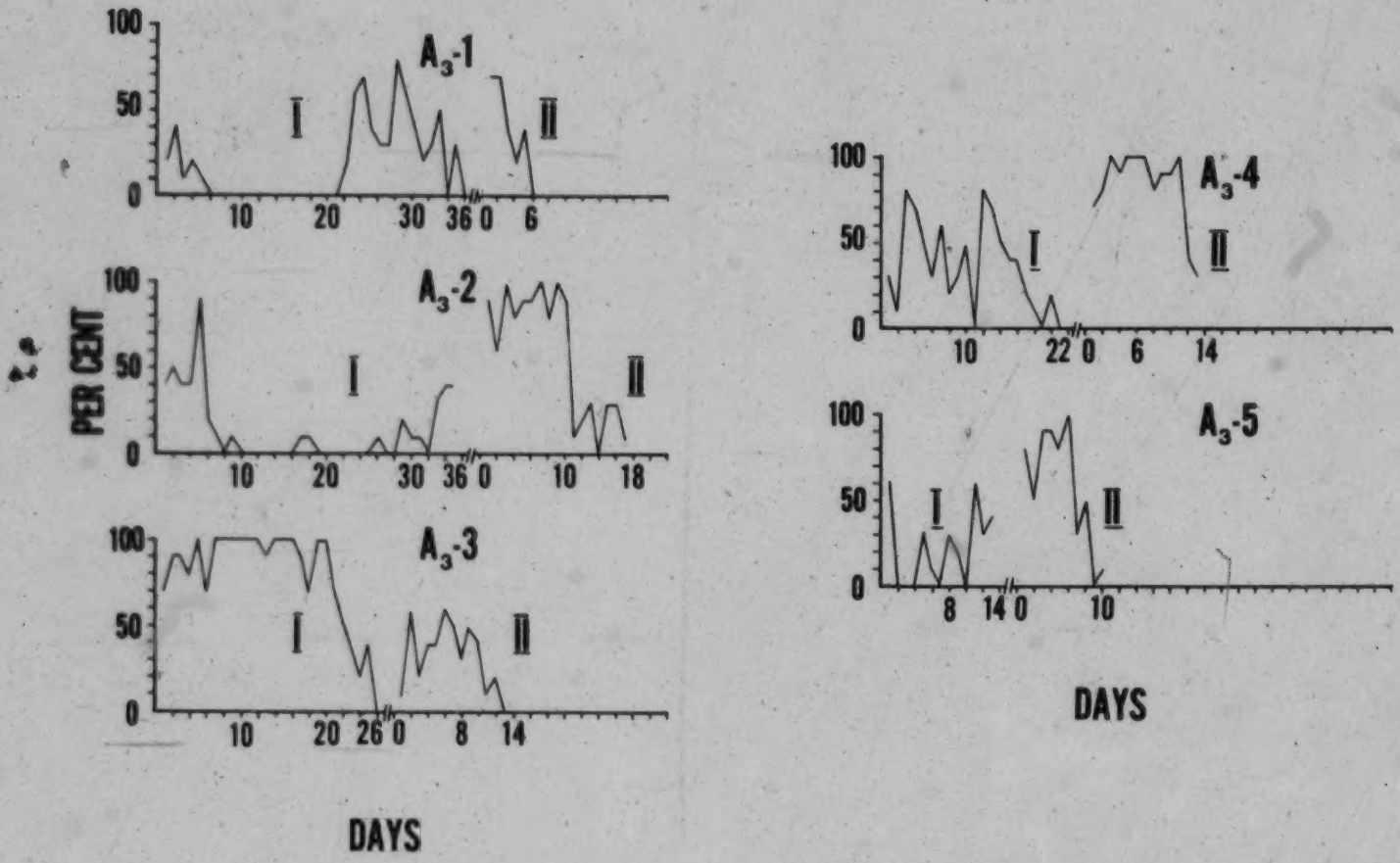


Figure 25. Color preferences in stages I and II for amatching group A_3. Equal responding to two CO colors is a zero preference; exclusive choice of one color is 100% preference.

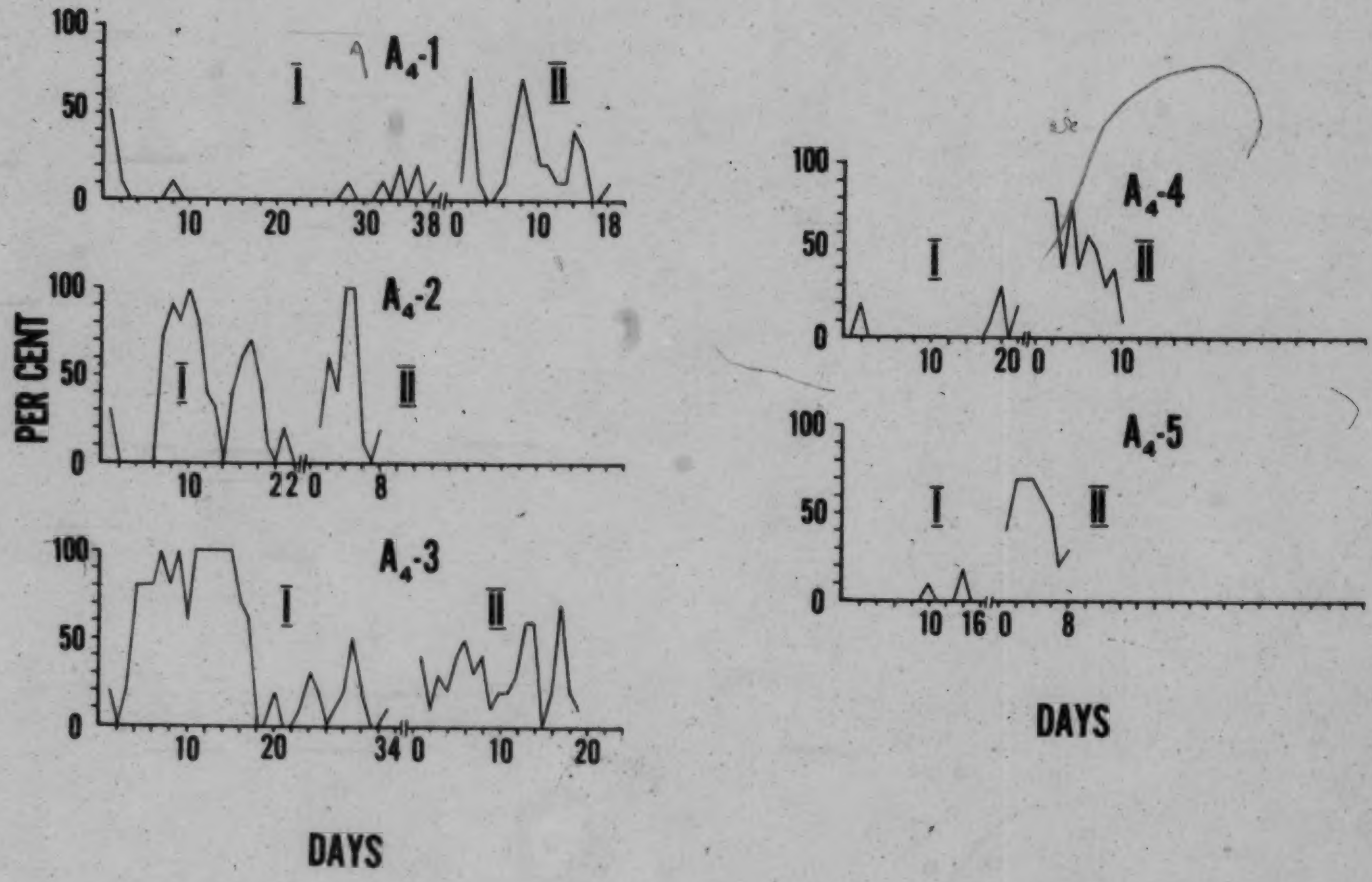


Figure 26. Color preferences in stages I and II for amatching group A_4. Equal responding to two CO colors is a zero preference; exclusive choice of one color is 100% preference.

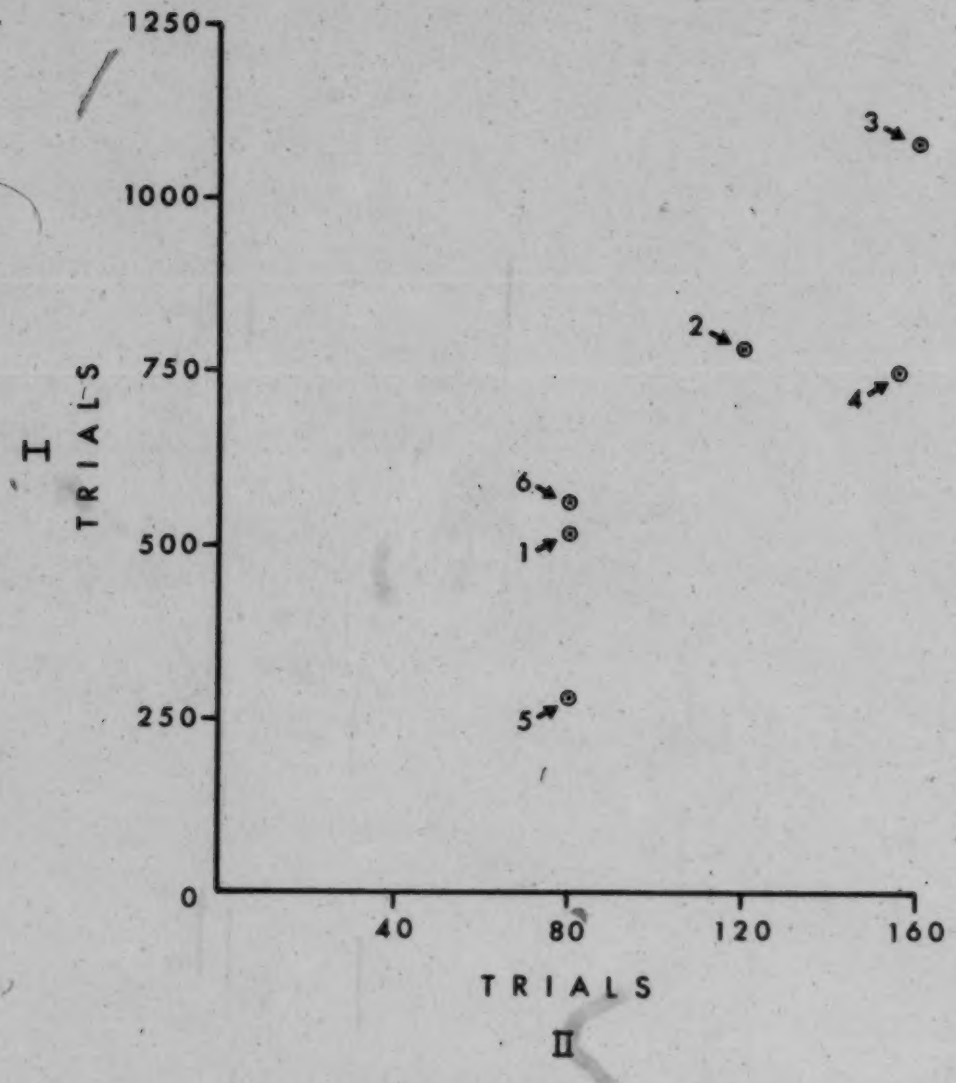


Figure 27. Correlation of trials to criterion in stages I and II for group A_1.